Geologic Overview of Southern California Mountain Ranges

- Plate Tectonics – Big Picture
- Fault Mechanics
- California Geology – Big Picture
- Southern California – Tectonic Development
- Peninsular Ranges
  - Santa Ana Mountains
  - San Joaquin Hills
- Economic Geology of PRB

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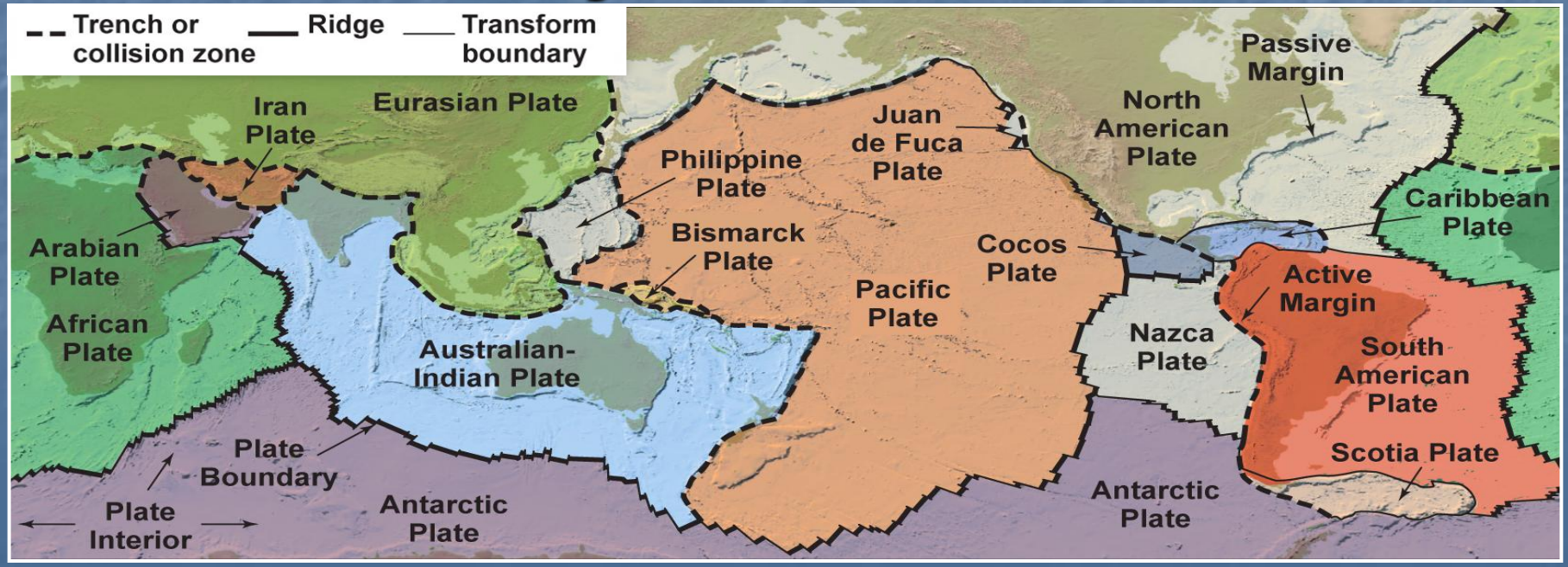
March 2012

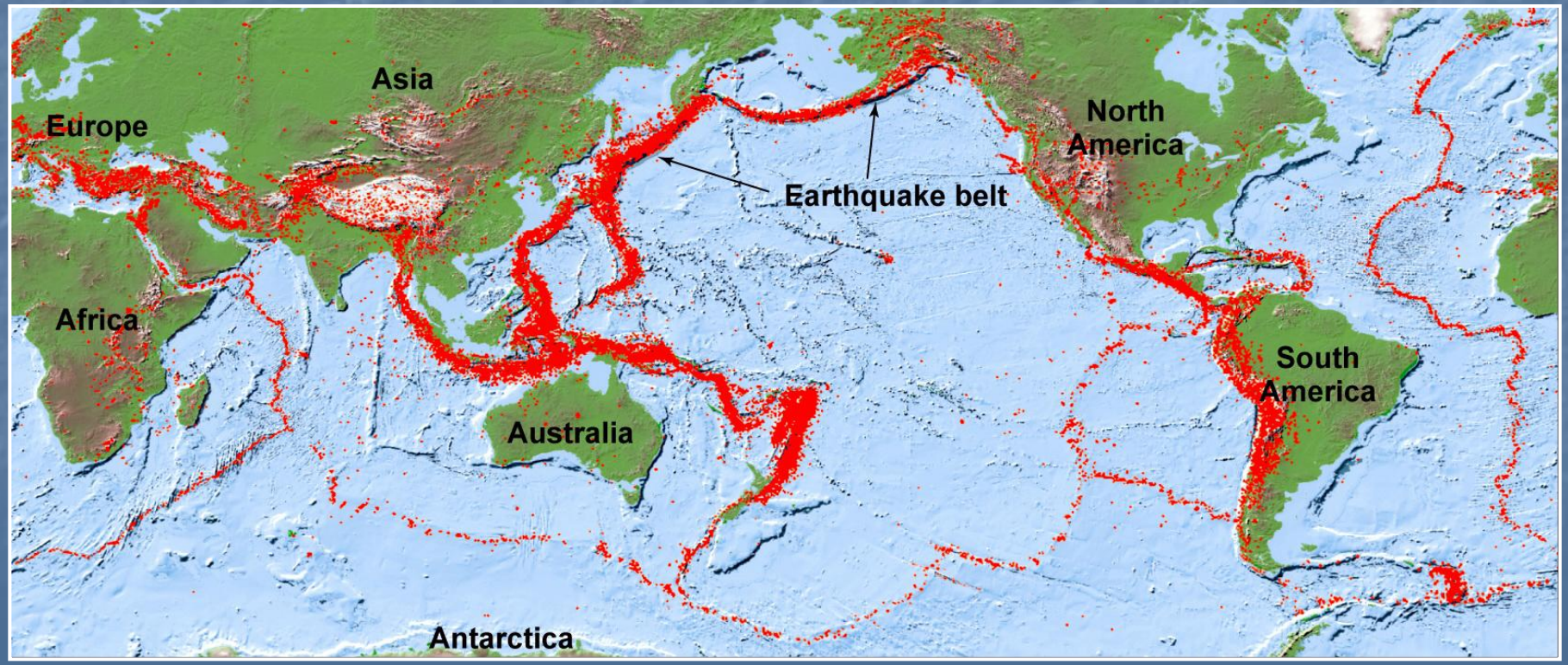
Plate Boundaries

- Lithosphere is fragmented into ~20 tectonic plates.
- Plates move continuously at a rate of 1–15 cm/year.
  - Slow on a human time scale; extremely rapid geologically.
- Plates interact along their boundaries.



Seismiscity Defines Boundaries

- Tectonic plates are identified by concentrations of earthquakes.
- Plate interiors are almost earthquake-free.



Continental Margins

- Where land meets the ocean.
  - Margins near plate boundaries are "active."
  - Margins far from plate boundaries are "passive."

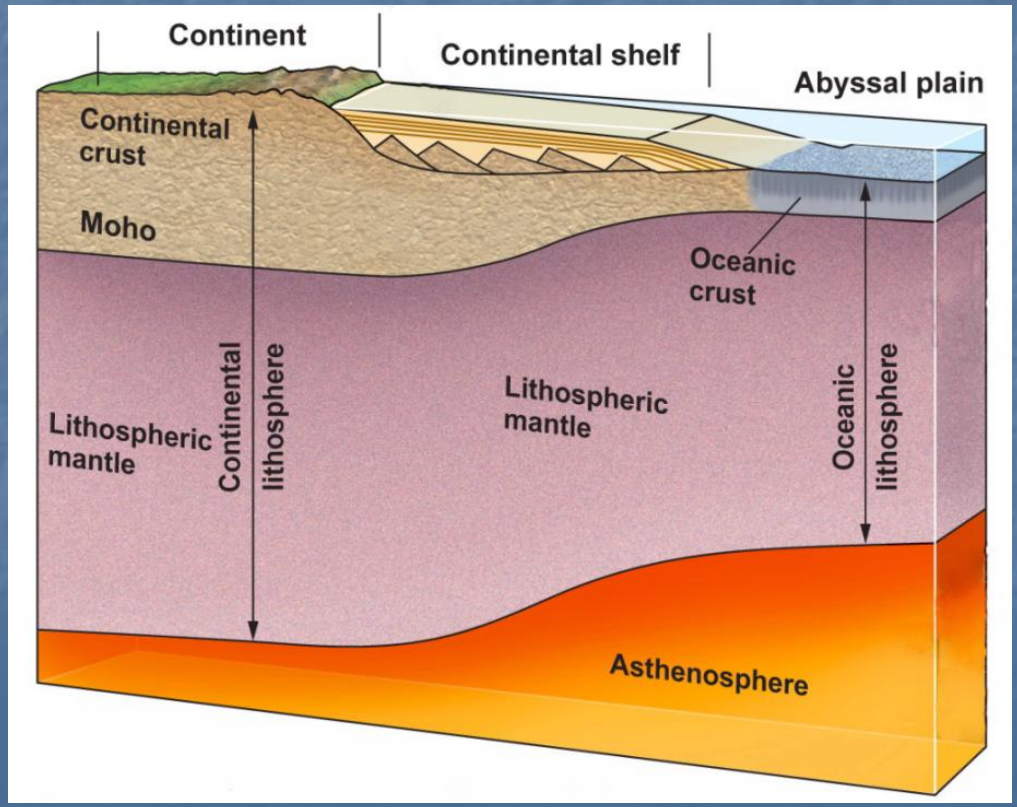
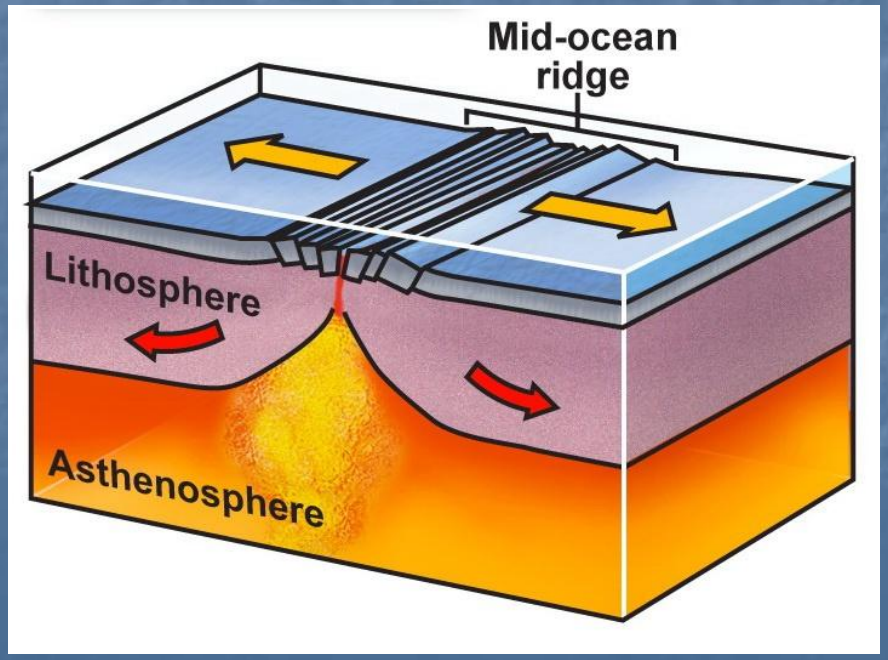


Plate Boundaries: Divergent

- Divergent boundary—tectonic plates move apart.
  - Lithosphere thickens away from the ridge axis.
  - Also called: spreading boundary, mid-ocean ridge, ridge.



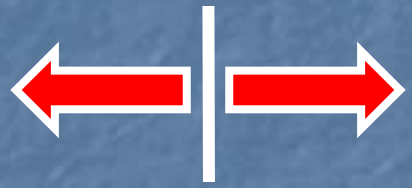
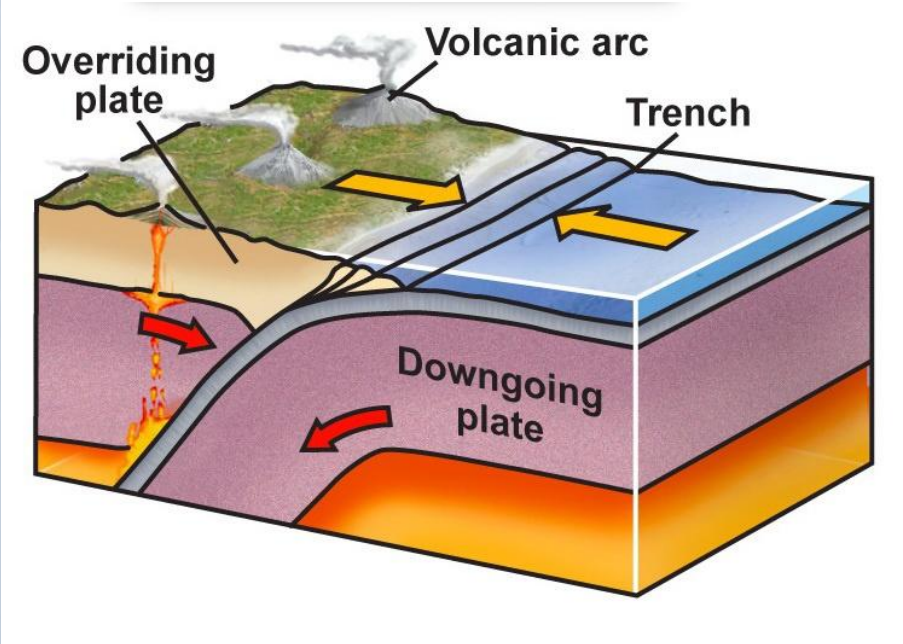


Plate Boundaries: Convergent

- Convergent boundary—tectonic plates move together.
  - The process of plate consumption is called subduction.
  - Also called: convergent margin, subduction zone, trench.



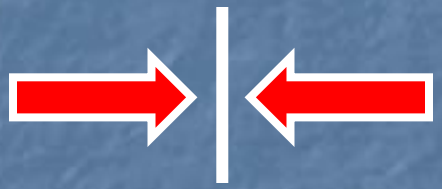
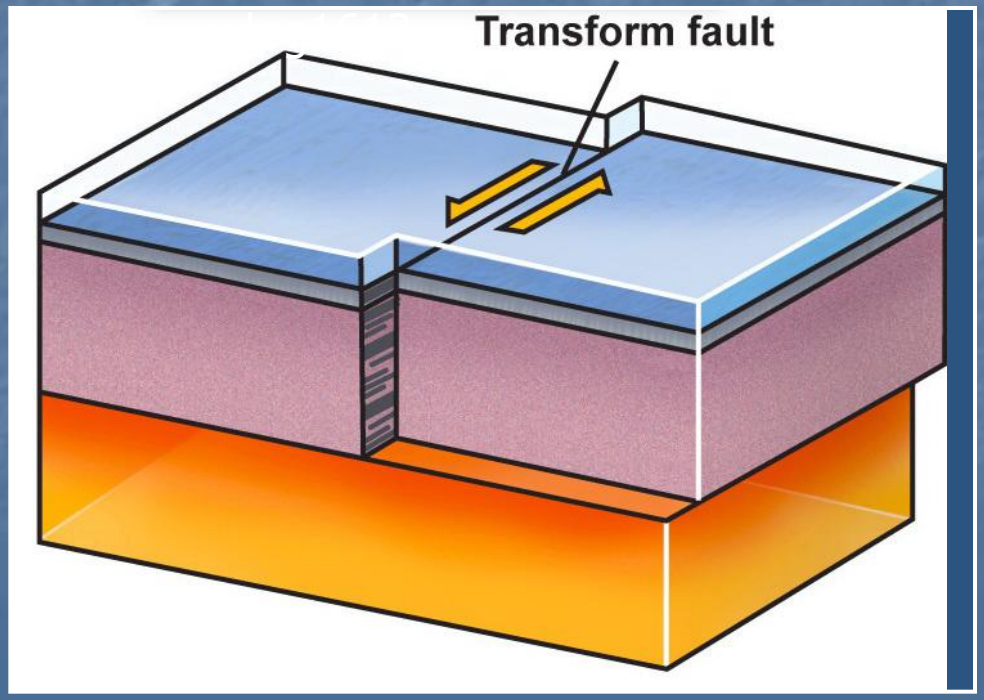
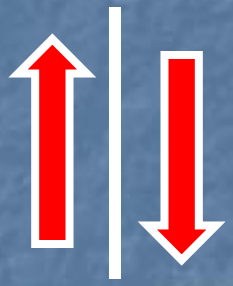


Plate Boundaries: Transform

- Transform boundary—tectonic plates slide sideways.
  - Plate material is neither created nor destroyed.
  - Also called: transform fault, transform.





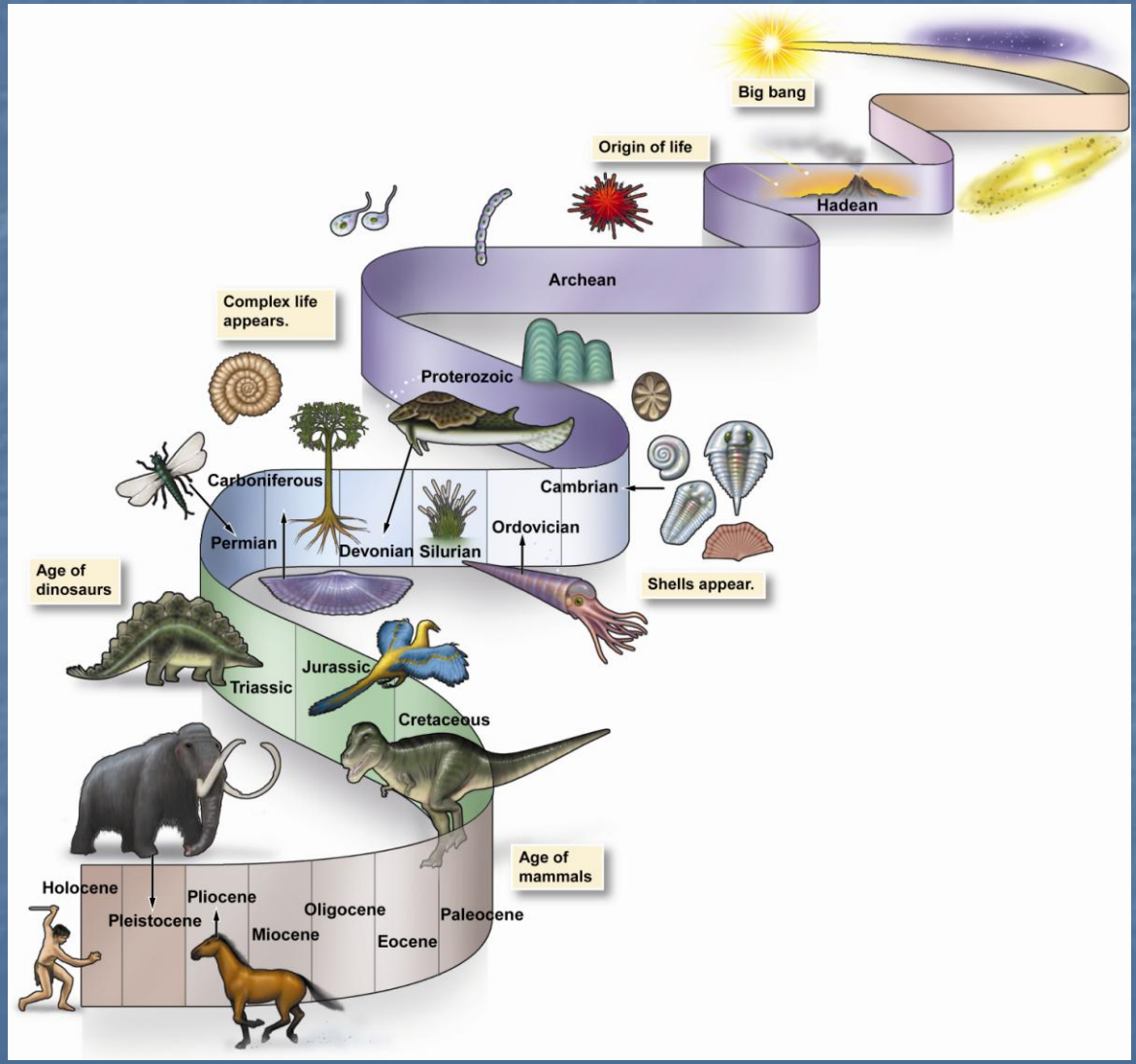
Geologic Time Scale – 4.56 Billion Years

- Life first appeared on Earth ~3.8 Ga.

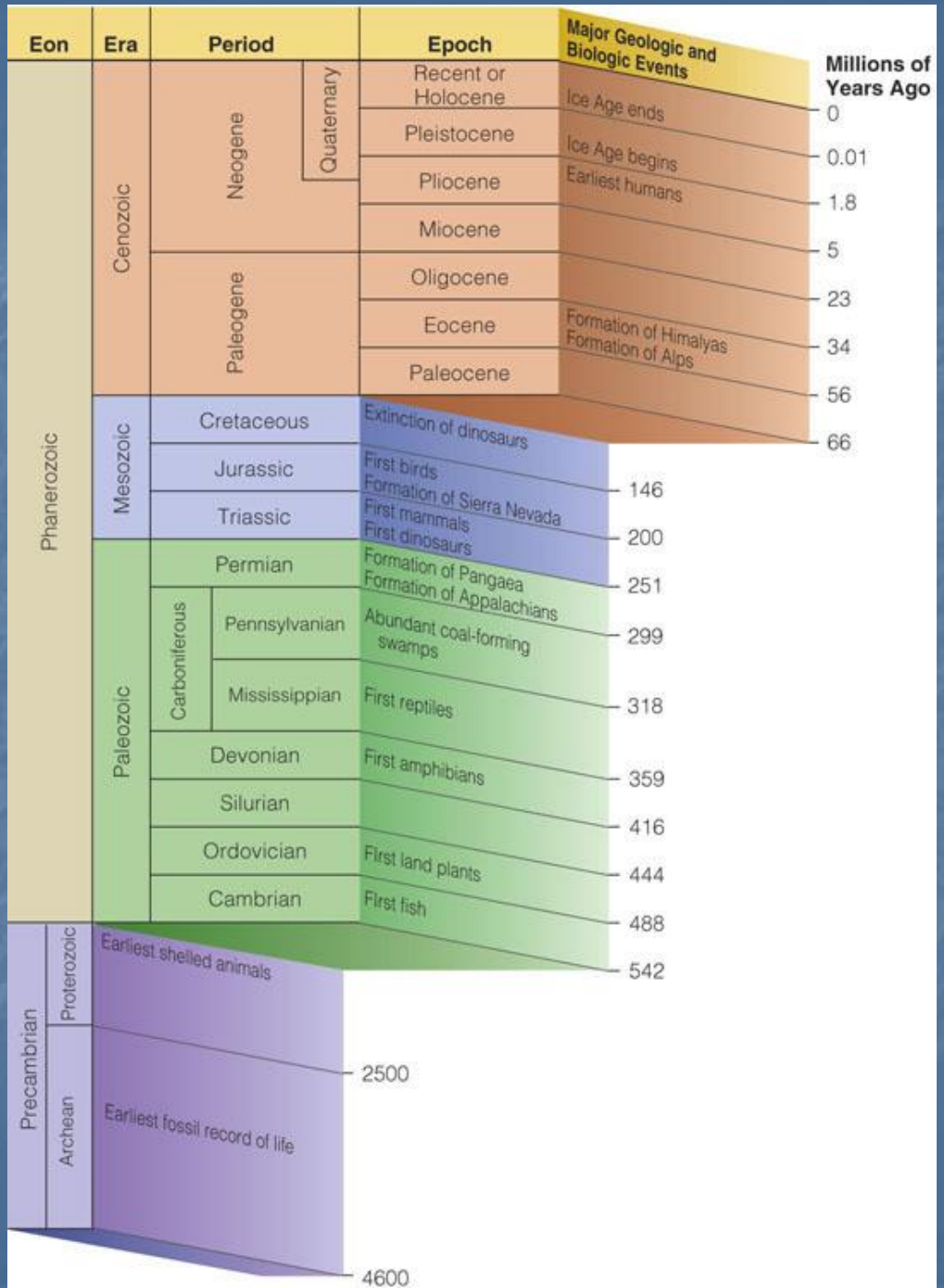
  Around 542 Ma marks the

  first appearance

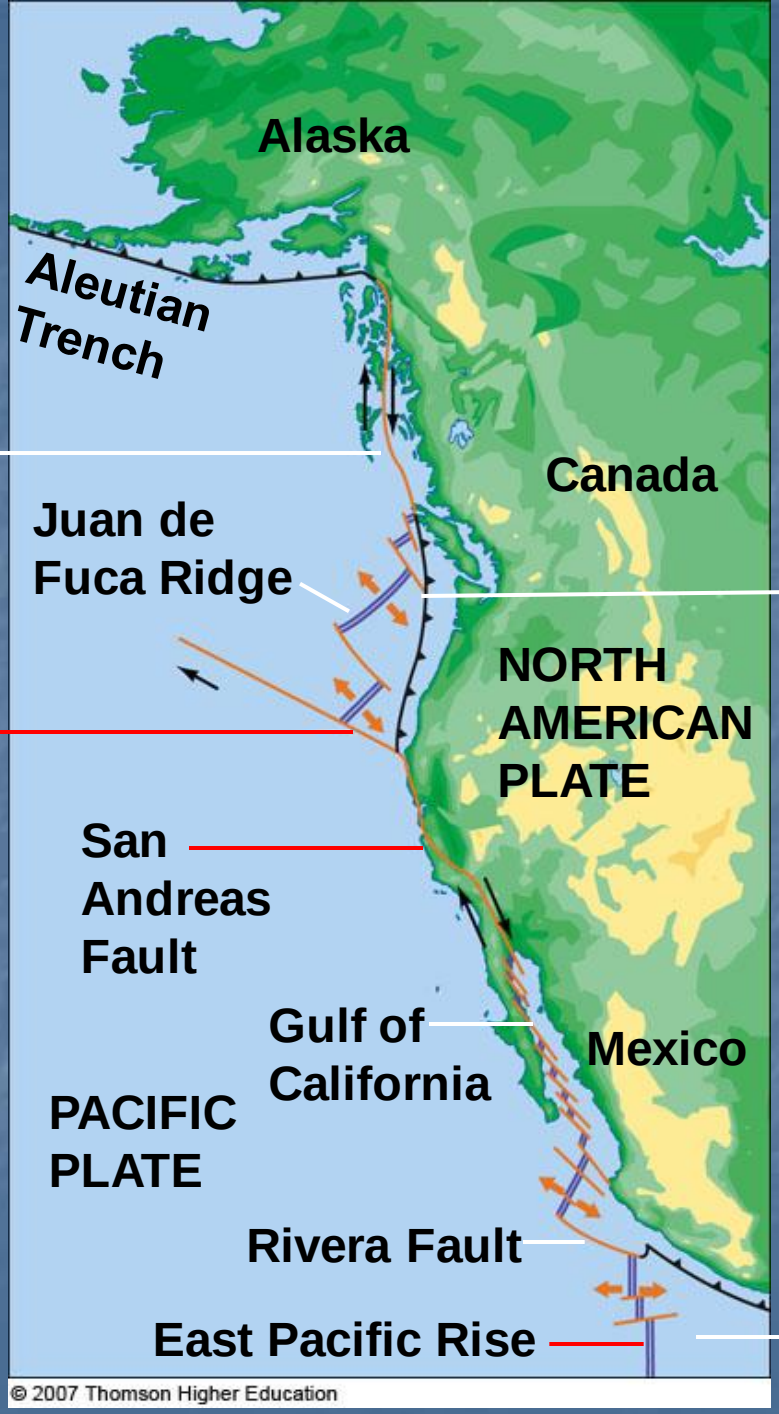
  of hard shells.



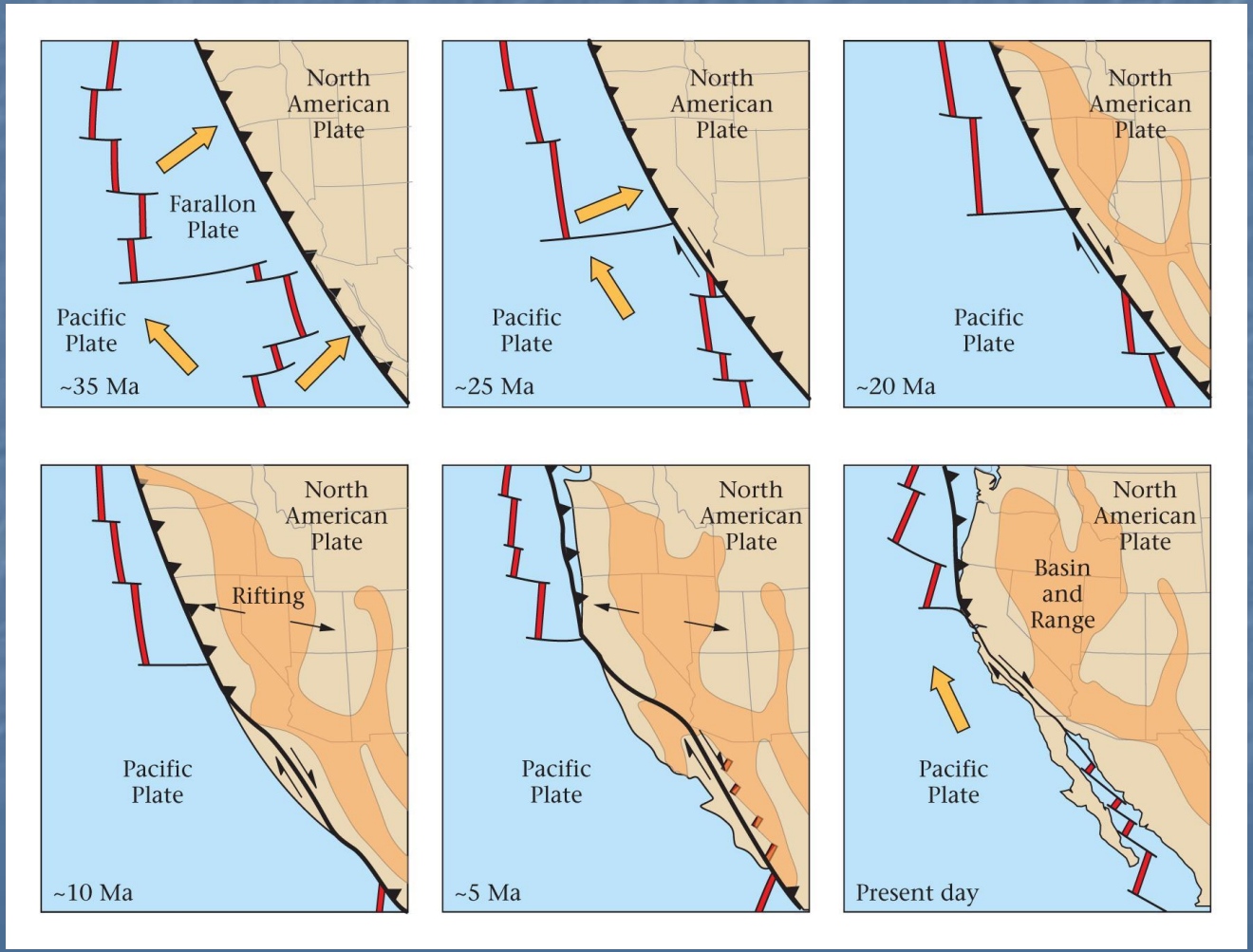
Geologic Time Scale



Western U.S. Transform Boundary



Cenozoic Plate Margin Changes for Western North America



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Physiography of S. California

Physiography of S. California + SAF

San Andreas EQ's

1857

m=7.9
220 mi rupture
Offset 31'

1906

m=7.9
265 mi rupture

Owen's Valley Fault 1873

m=7.3

EQ Intervals for Southern San Andreas Fault (from Grant et al., 2010)

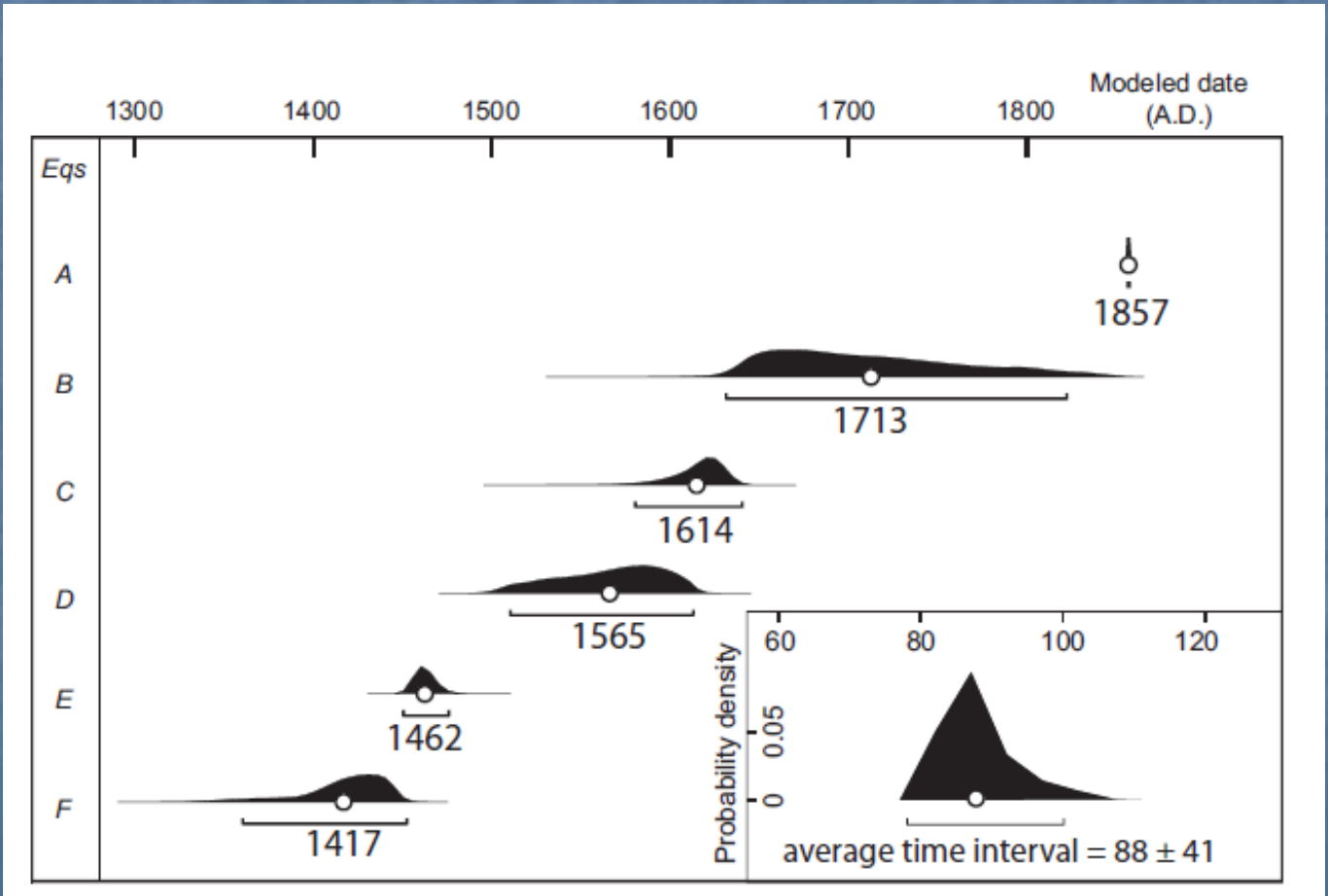

Plate Velocity along San Andreas Fault

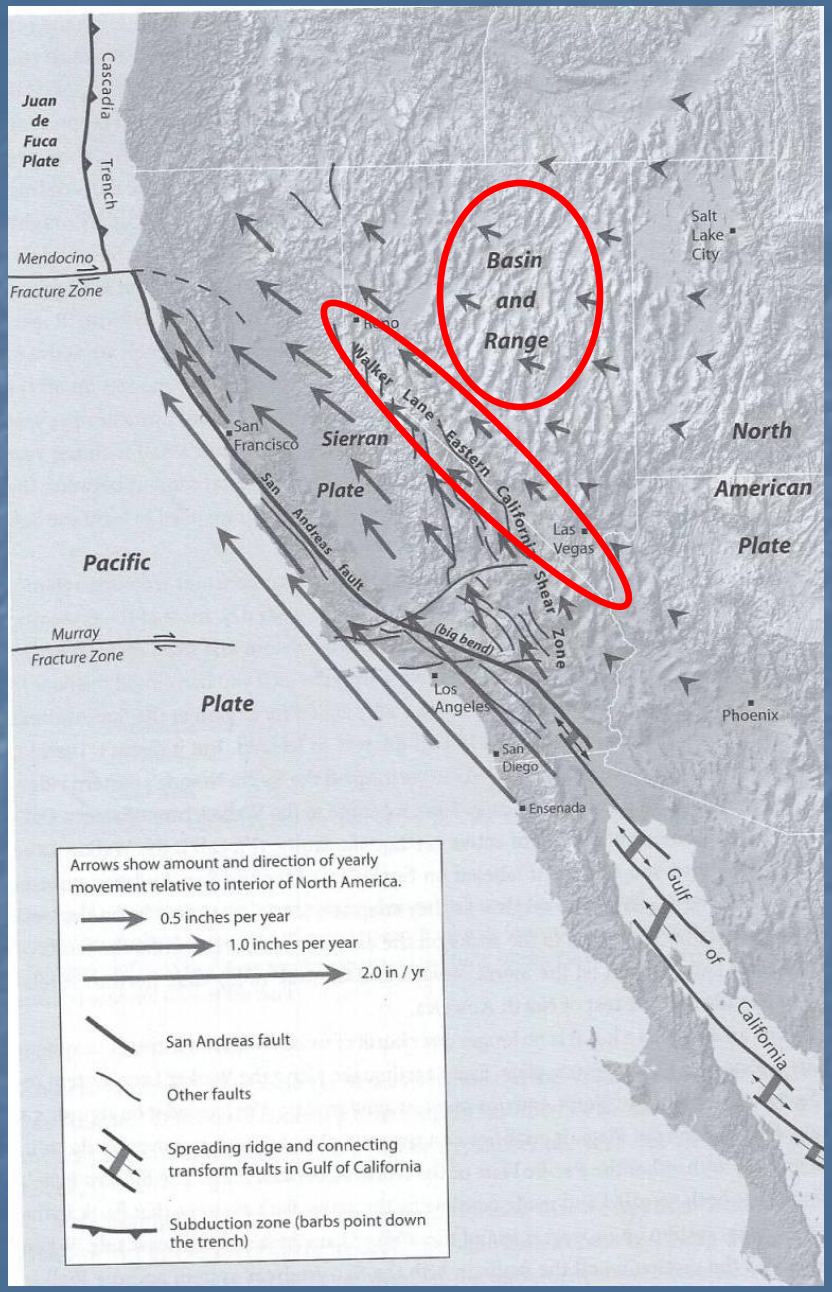

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Plate Configuration 15 m.y. in future San Andreas Motion most significant

LA moves towards SF Bay

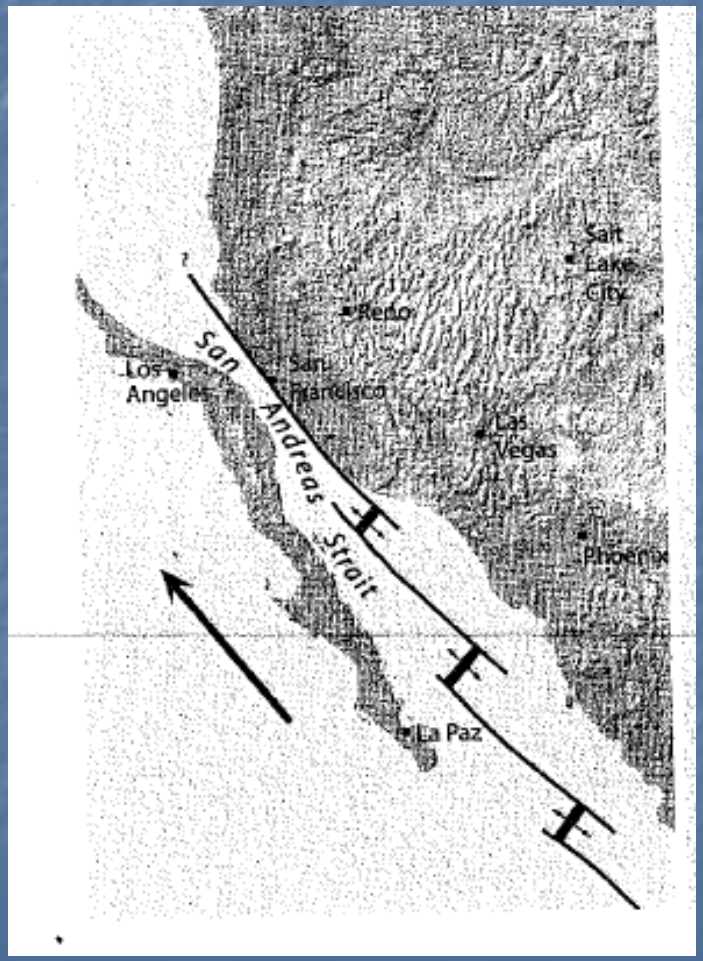

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Plate Configuration 15 m.y. in future
Walker Lane Motion most significant

All of CA west of Sierra Nevada moves northwest

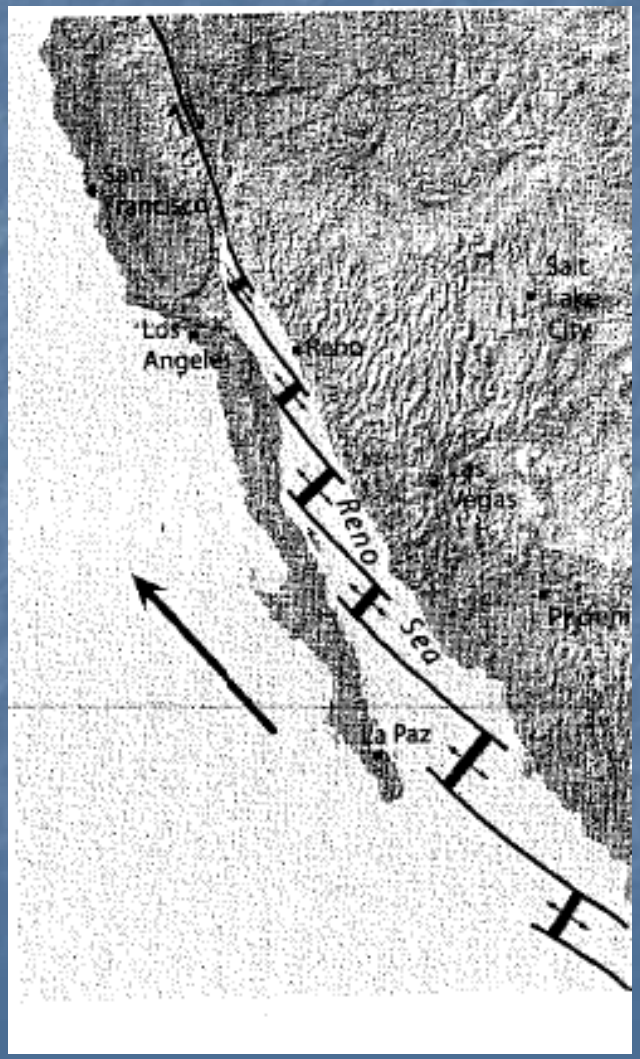

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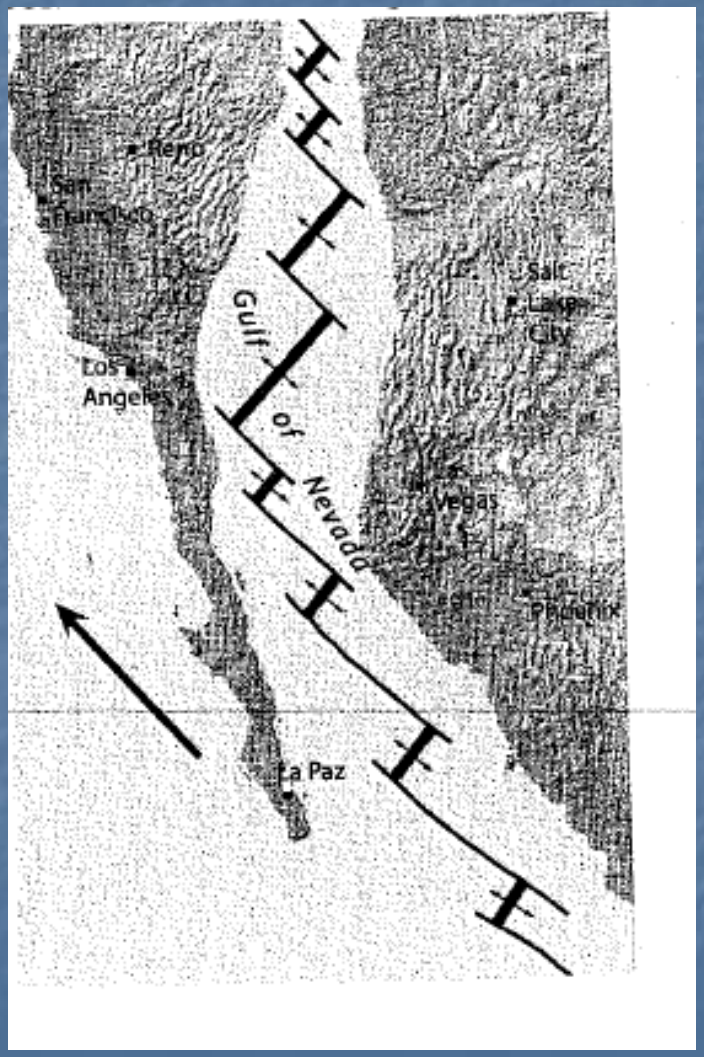
Plate Configuration 15 m.y. in future Basin/Range Motion most significant

Rift through Basin & Range moves CA, OR, WA, and w. NV northwest



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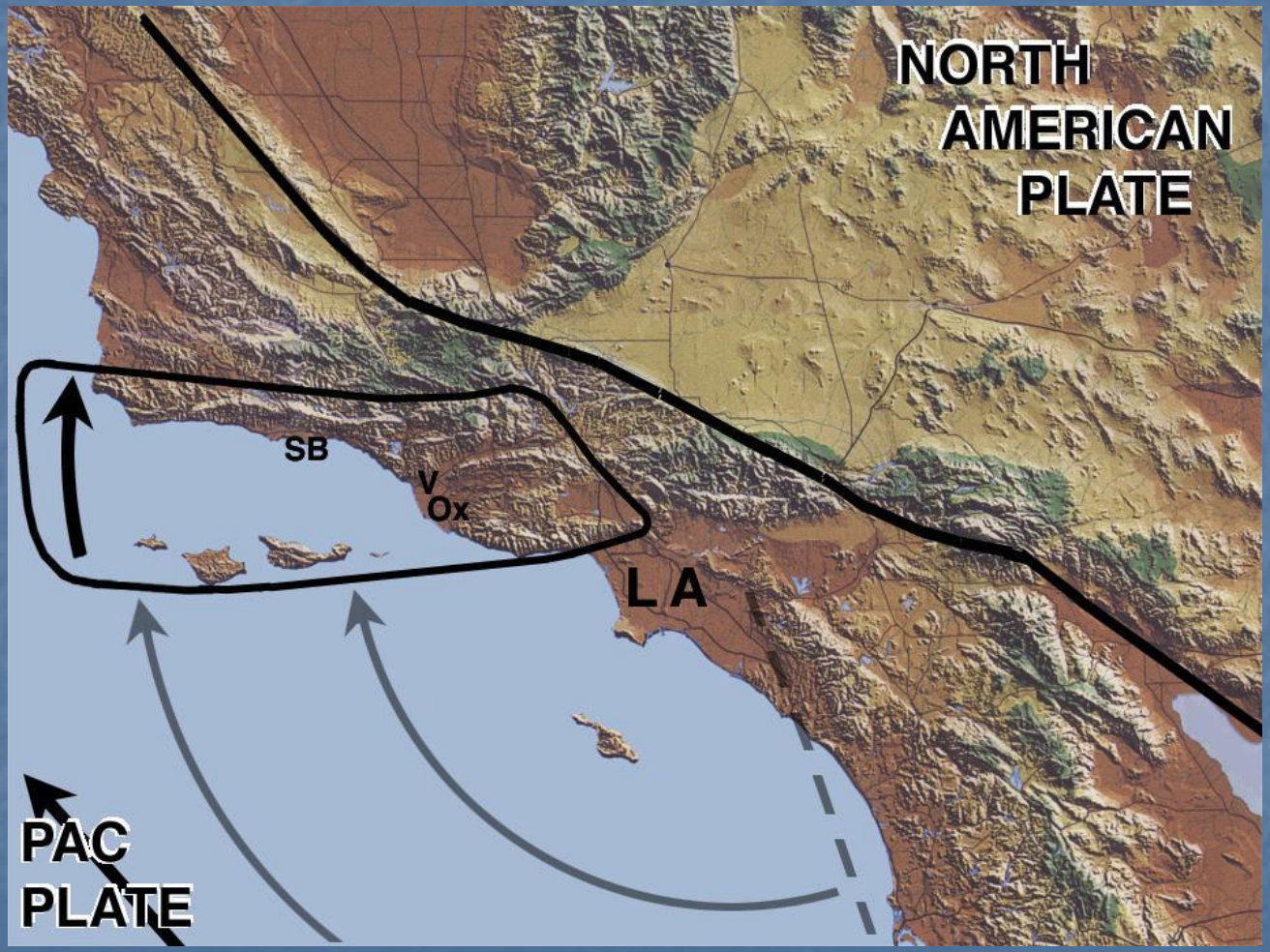
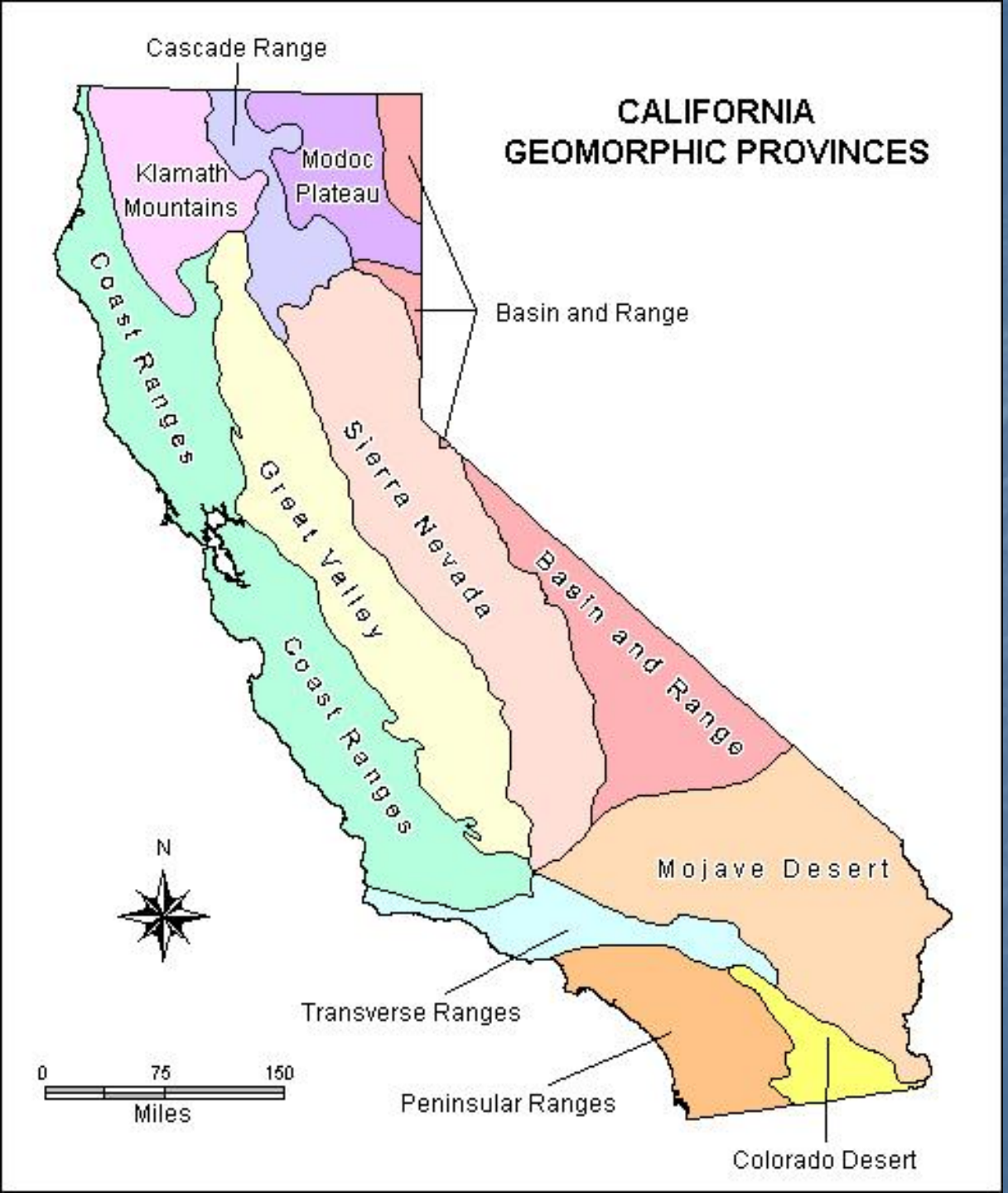
Rotation of Transverse Ranges



Animated Tectonic Models UCSB

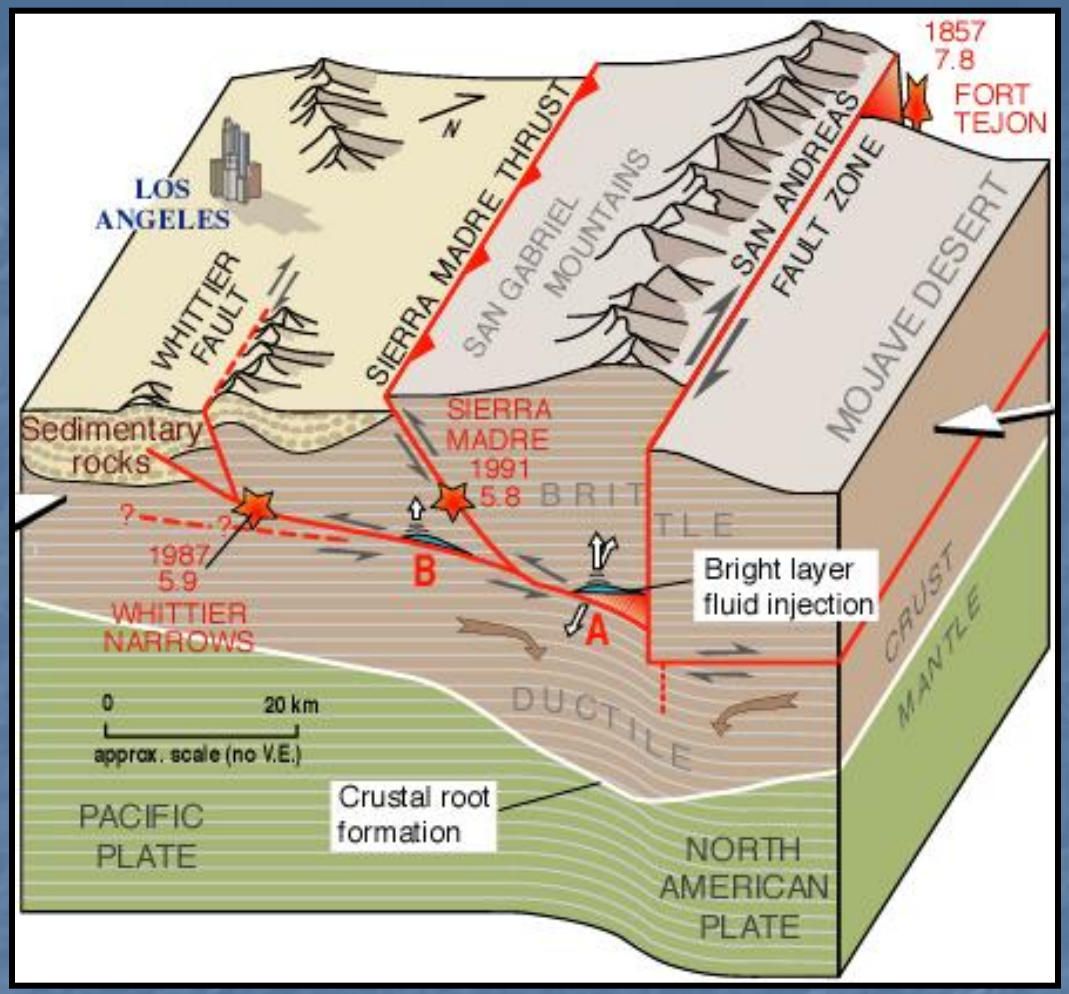
http://animations.geol.ucsb.edu/1_DownloadPage/Download_Page.html#GlobalTectonics

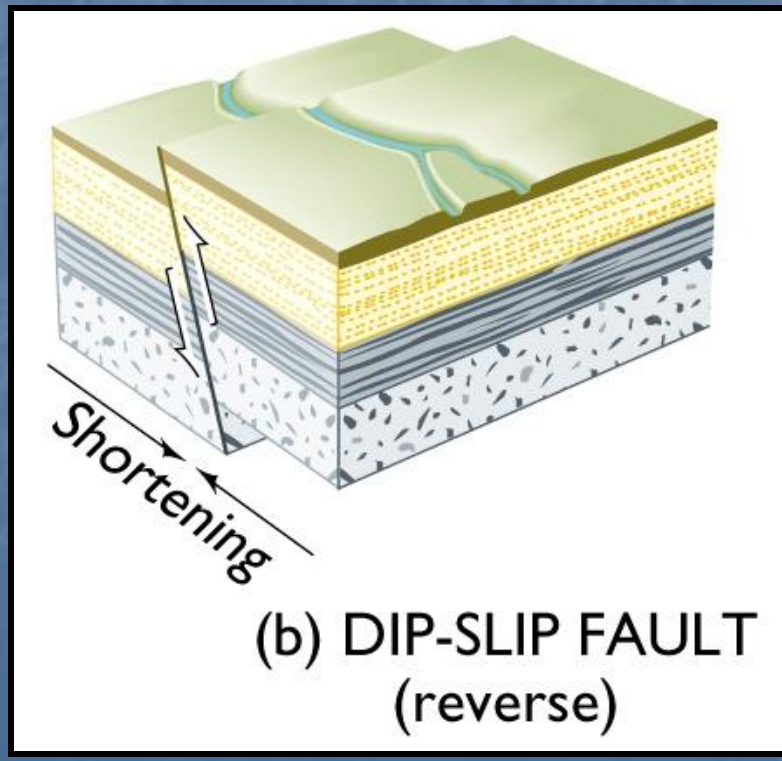

CALIFORNIA
GEOMORPHIC PROVINCES
Cascade Range
Klamath Mountains
Modoc Plateau
Basin and Range
Coast Ranges
Great Valley
Sierra Nevada
Basin and Range
Coast Ranges
Mojave Desert
N
Transverse Ranges
Peninsular Ranges
Colorado Desert
0
75
150
Miles

Geomorphic Detail of S. California

http://scamp.wr.usgs.gov/scgeo

Compression at "Big Bend" creates uplifted mountains/ islands, folds & reverse faults





Peninsular Ranges

Mountain Ranges: Santa Ana, San Jacinto, Santa Rosa, Palomar, San Diego

Rivers: San Diego River, Tijuana River, Santa Ana River

Mountains: Santiago Peak (5,687 ft), San Jacinto Peak (10,804 ft), Mt. Palomar (6,140 ft)

Rock types: Mesozoic intrusive igneous rocks (granites) and Mesozoic volcanic rocks; Cenozoic sedimentary rocks

Faults: Newport-Inglewood, Elsinore, San Jacinto, Banning, San Andreas

Resources: Gemstones, aggregates, Au, Ag

Peninsular Range Batholith emplaced 140-80 Ma

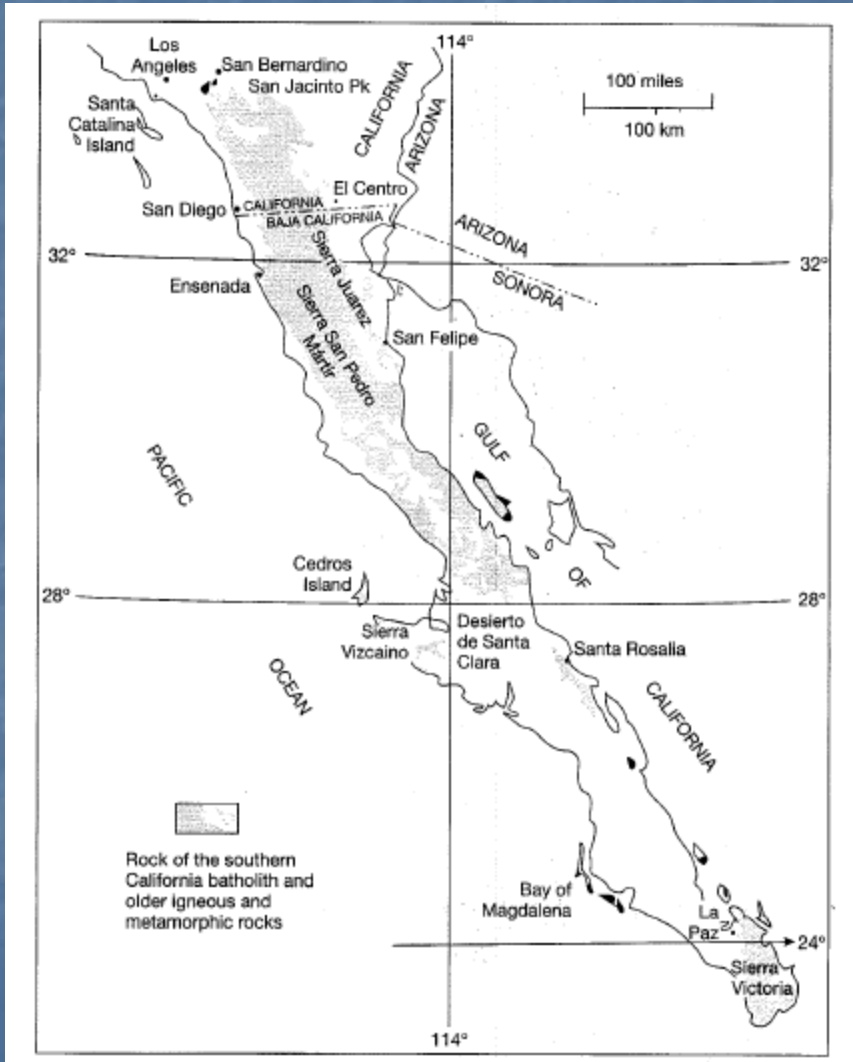
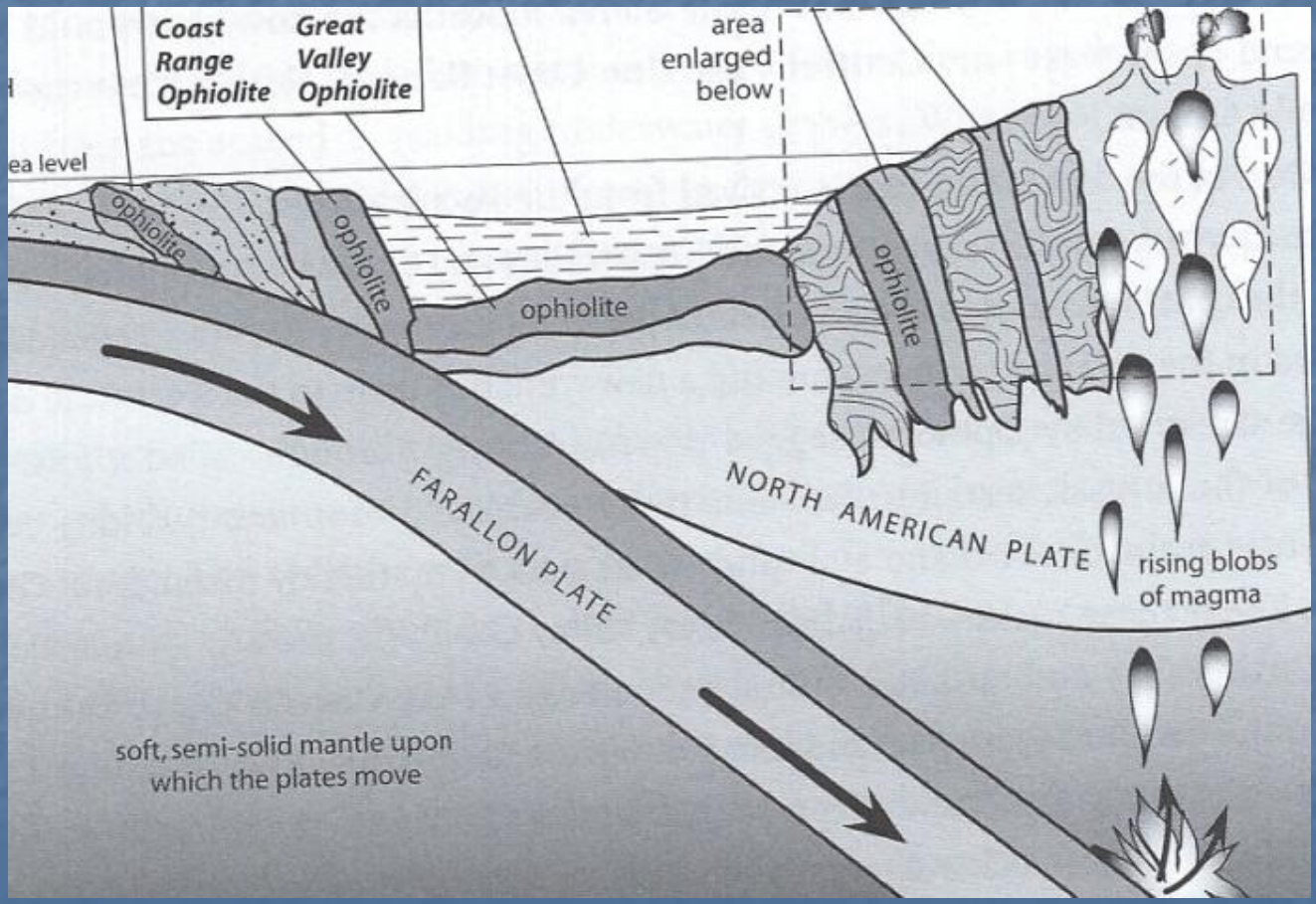


Fig. 17-1 Map showing the extent of the Peninsular Range batholith in southern California and Baja California, Mexico. (Source: Jahns, R. 1954. *Geology of Southern California*, Bulletin

Subduction of Farallon Plate created the Peninsular Batholith



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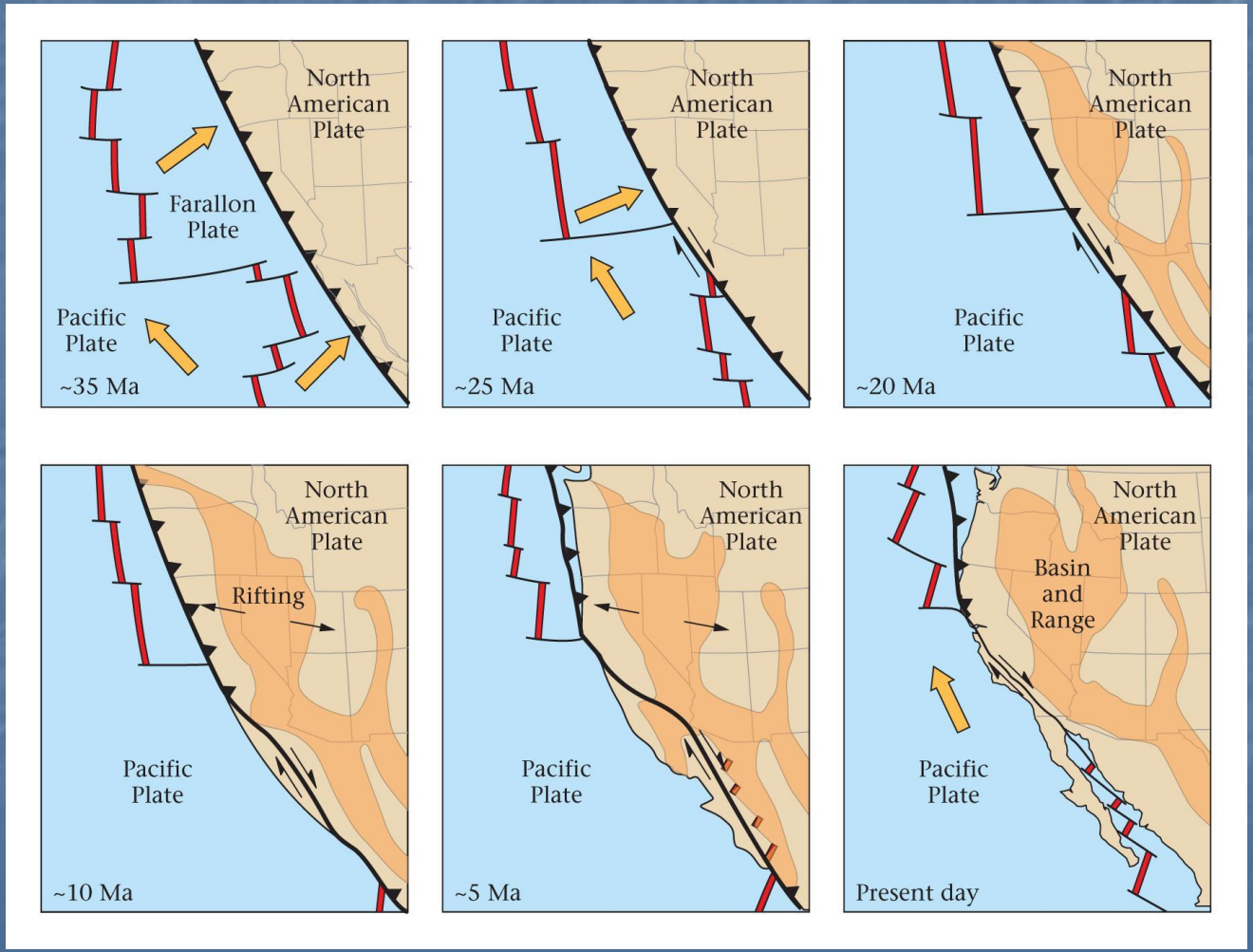
Cenozoic Plate Margin Changes for Western North America



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Eastern vs. Western PRB

Western belt has more mafic rocks

Eastern belt has more felsic rocks

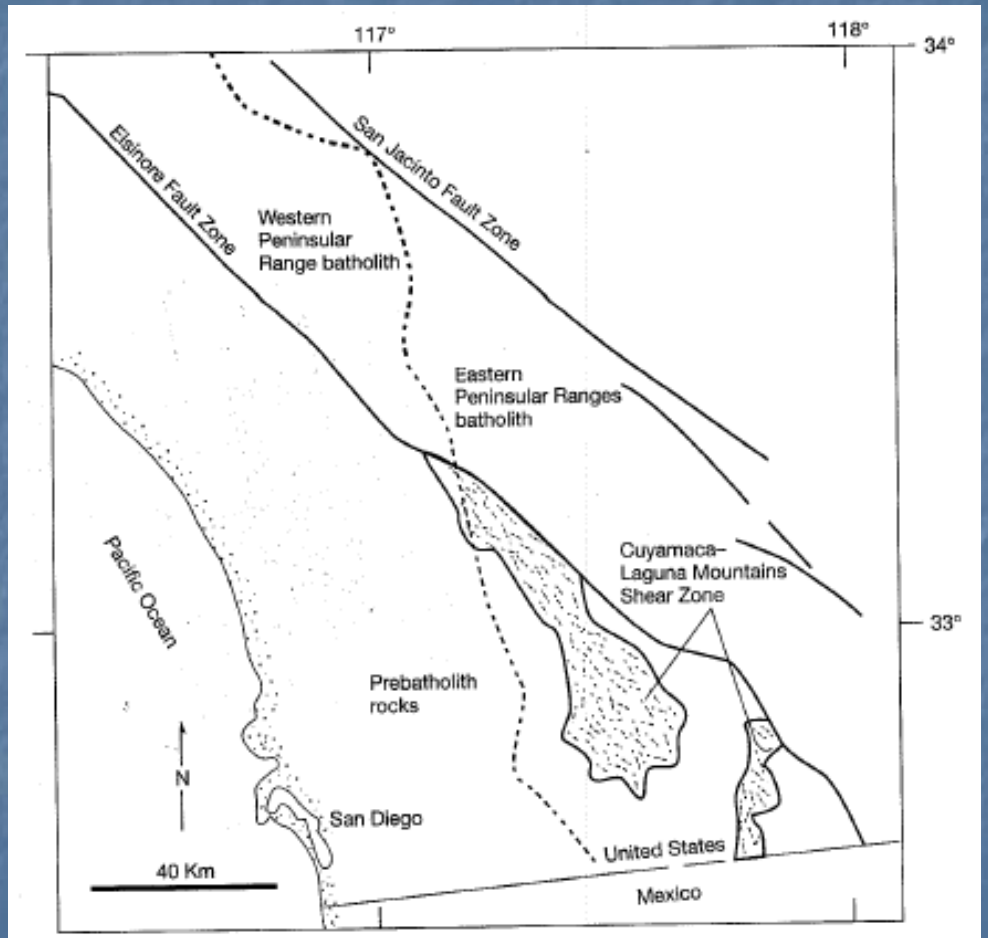


Fig. 17-2 The eastern and western parts of the Peninsular Ranges batholith and the Cuyamaca–Laguna Mountains shear zone, which lies along the boundary. The approximate

Granites

Quartz, feldspars, micas, hornblende

Granite

Granodiorite

http://virtual.yosemite.cc.ca.us/ghayes/granite.htm

Gabbro and Diorite

Feldspars, pryoxene, hornblende (more Fe, Mg-rich minerals)

Gabbro (black granite)

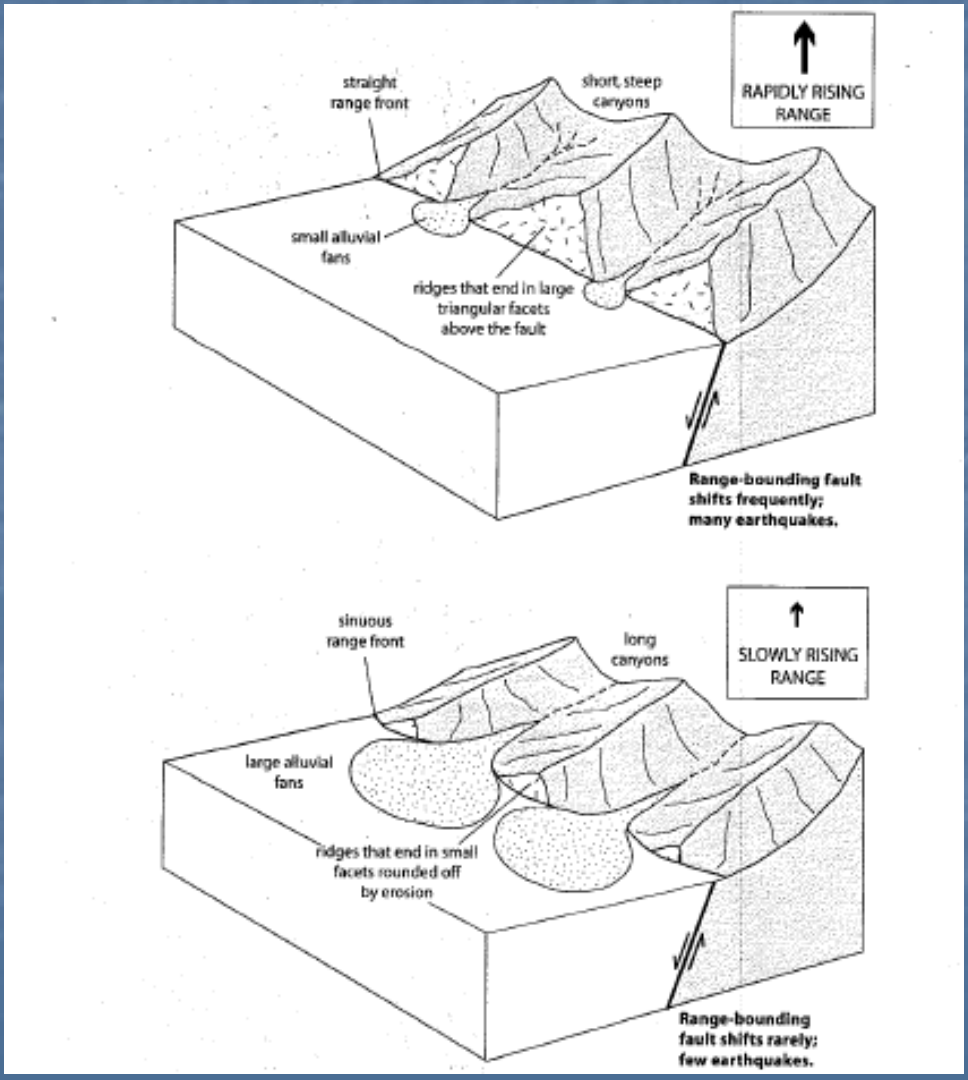
Diorite

Eastern vs. Western PRB

Western belt: Formed during the early Cretaceous by subduction beneath an oceanic island arc

Eastern belt: Formed in later Cretaceous time from a source rock that included a continental (silica-rich) component – implies eastward shift in magmatic activity.

Range Bounding Faults



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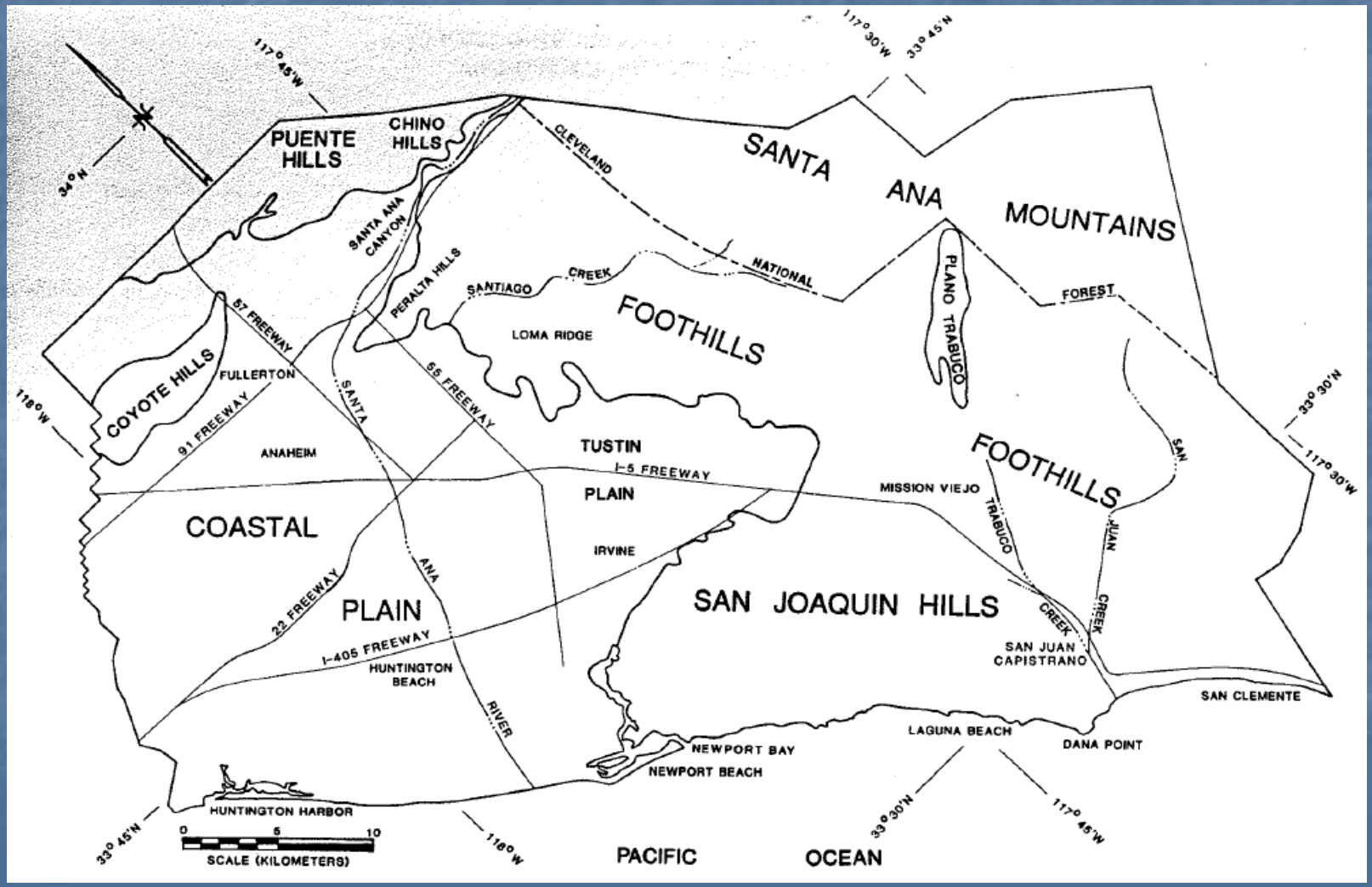
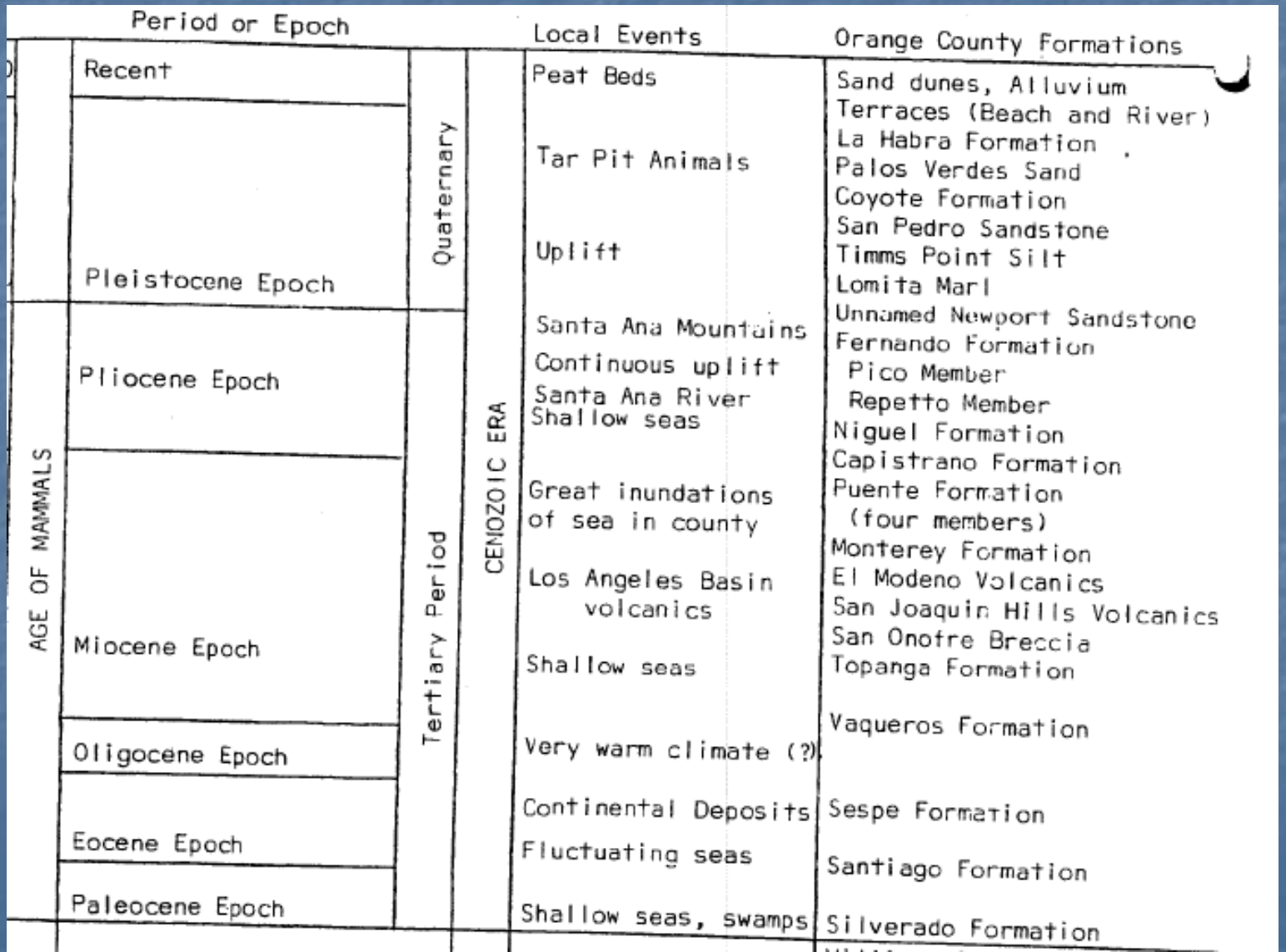
Prebatholith Rocks in the Peninsular Ranges

- Bedford Canyon Formation
  - Marine turbidites deposited in offshore basins during the Jurassic (Bedford Canyon metasedimentary rocks are exposed in Santa Ana Mts)
- Julian Schist
  - Metasedimentary rocks formed from shale deposited in submarine fans
- Santiago Peak Volcanics
  - Forms the western edge of the peninsular batholith in southern California. It is composed of volcanic, volcaniclastic rocks of Cretaceous age (130 to 120 Ma).

Physiographic Map of Orange County

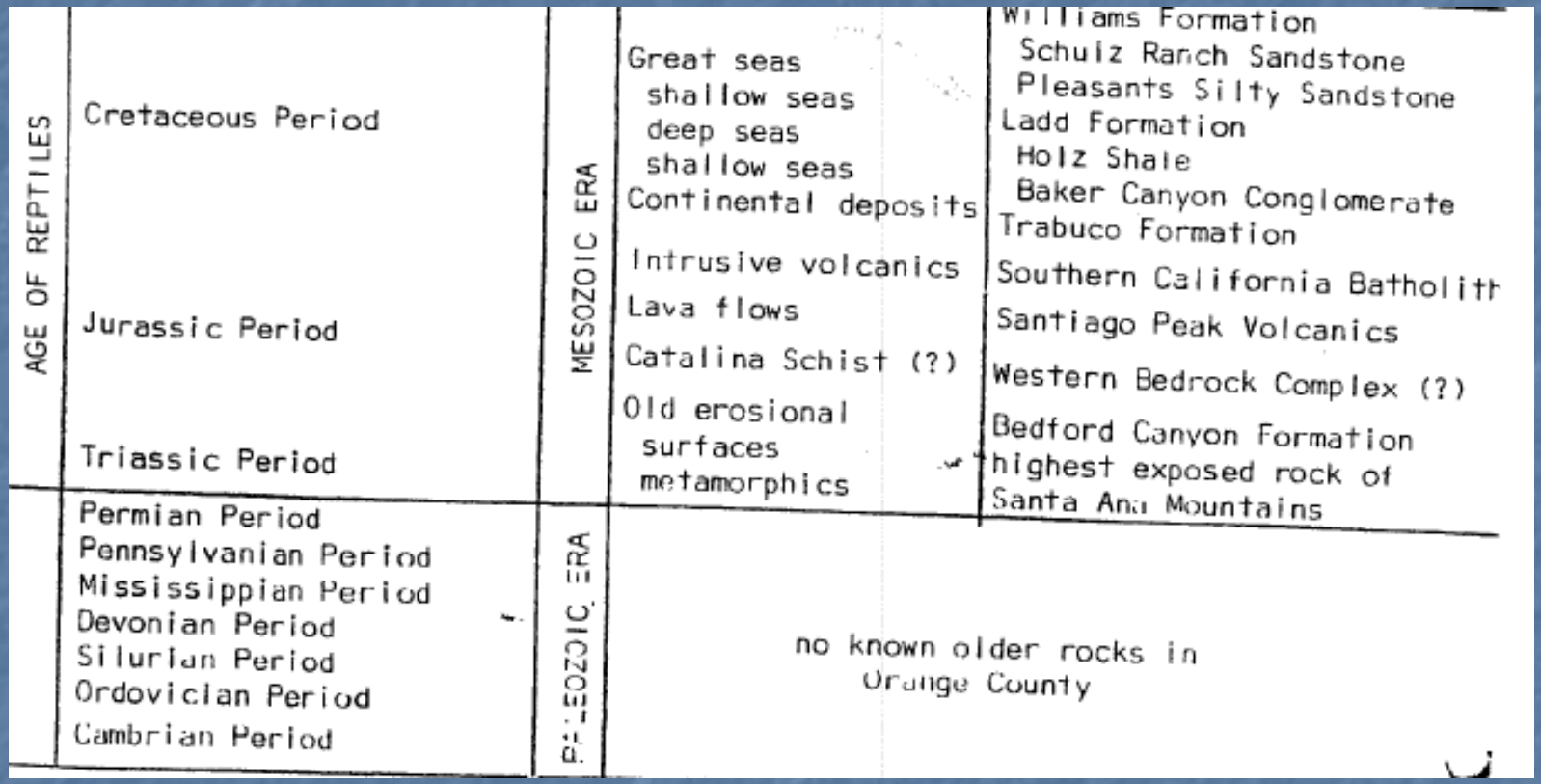


Geologic Time Scale – OC Area



Period or Epoch				Local Events	Orange County Formations
AGE OF MAMMALS	Recent	Quaternary	CENOZOIC ERA	Peat Beds	Sand dunes, Alluvium Terraces (Beach and River)
	Pleistocene Epoch			Tar Pit Animals Uplift	La Habra Formation Palos Verdes Sand Coyote Formation San Pedro Sandstone Timms Point Silt Lomita Marl
	Pliocene Epoch	Tertiary Period		Santa Ana Mountains Continuous uplift Santa Ana River Shallow seas	Unnamed Newport Sandstone Fernando Formation Pico Member Repetto Member Niguel Formation
	Miocene Epoch			Great inundations of sea in county Los Angeles Basin volcanics Shallow seas	Capistrano Formation Puente Formation (four members) Monterey Formation El Modeno Volcanics San Joaquin Hills Volcanics San Onofre Breccia Topanga Formation
	Oligocene Epoch			Very warm climate (?)	Vaqueros Formation
	Eocene Epoch			Continental Deposits Fluctuating seas	Sespe Formation Santiago Formation
	Paleocene Epoch			Shallow seas, swamps	Silverado Formation

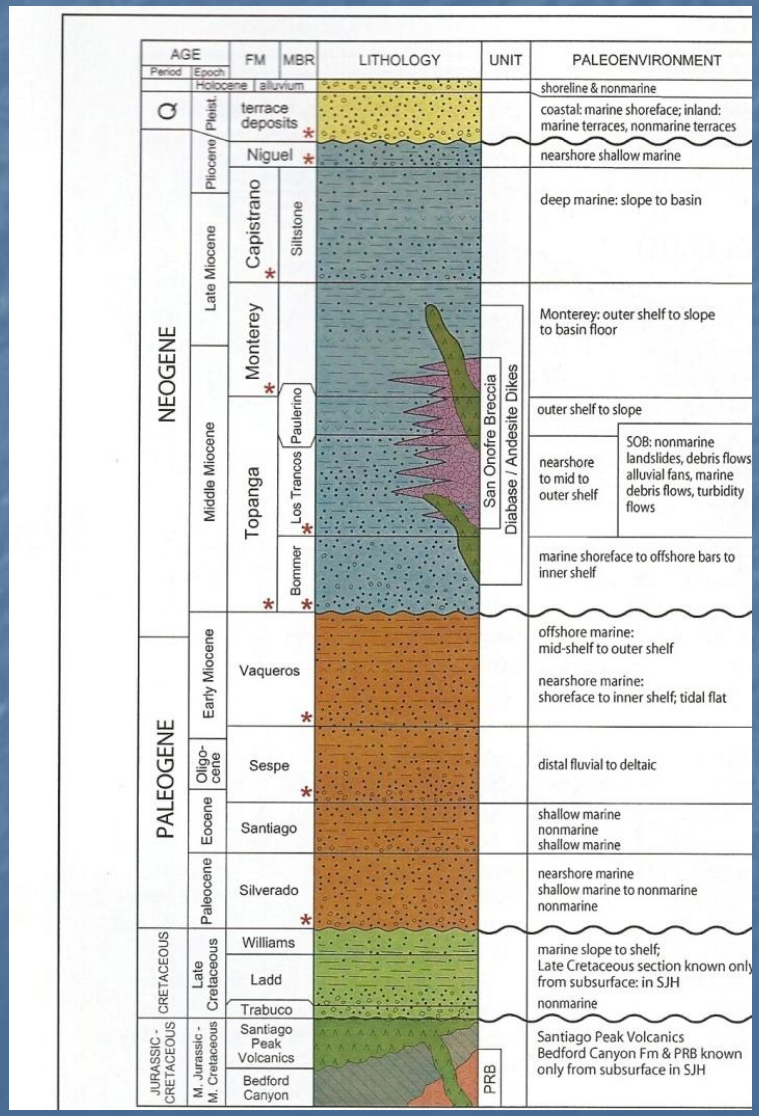
Geologic Time Scale – OC Area



AGE OF REPTILES	Cretaceous Period	MESOZOIC ERA	Great seas	Williams Formation Schulz Ranch Sandstone Pleasants Silty Sandstone
			shallow seas	Ladd Formation
			deep seas	Holz Shale
			shallow seas	Baker Canyon Conglomerate
			Continental deposits	Trabuco Formation
			Intrusive volcanics	Southern California Batholith
	Jurassic Period		Lava flows	Santiago Peak Volcanics
			Catalina Schist (?)	Western Bedrock Complex (?)
	Triassic Period		Old erosional surfaces metamorphics	Bedford Canyon Formation highest exposed rock of Santa Ana Mountains
	Permian Period Pennsylvanian Period Mississippian Period Devonian Period Silurian Period Ordovician Period Cambrian Period	PALEOZOIC ERA	no known older rocks in Orange County	

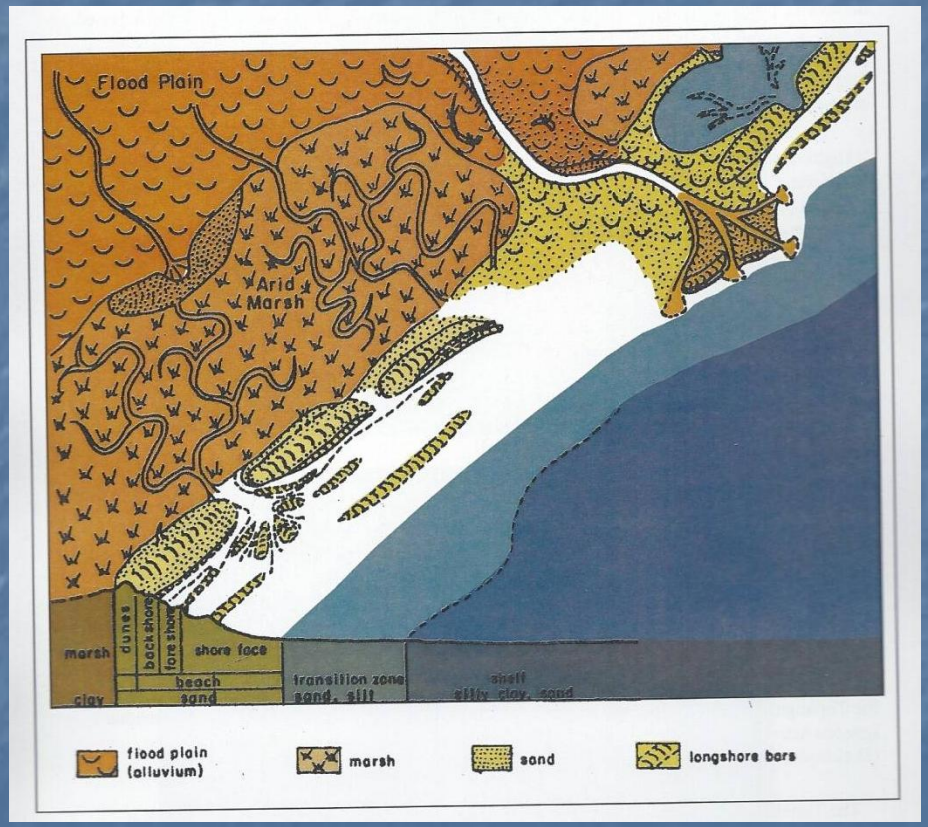
General Geology of Santa Ana Mts.

Geologic Column – OC Area



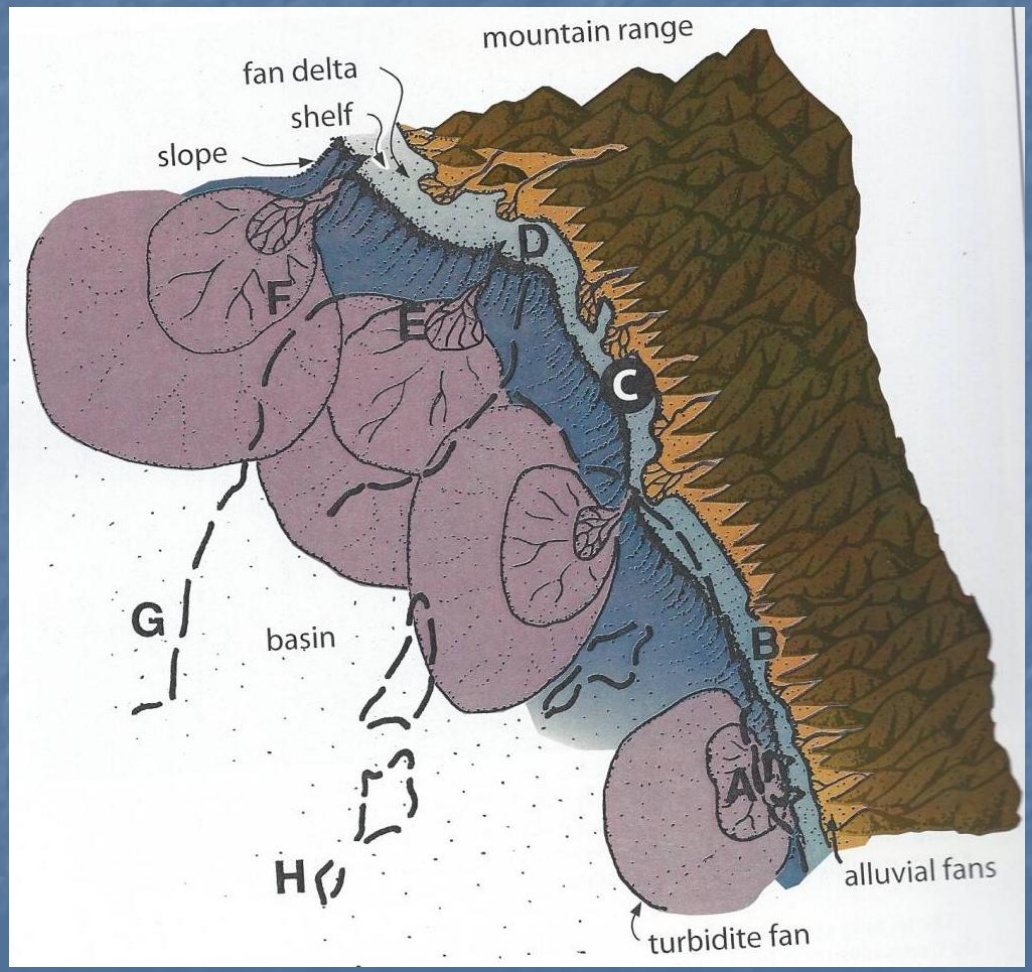
Fritsche & Behl, 2008

Paleogeographic Map of Sespe (orange) and Vasqueros (yellow/blue) Paleoenvironments



Fritsche & Behl, 2008

Paleogeographic Map of S. California in late Cretaceous



Fritsche & Behl, 2008

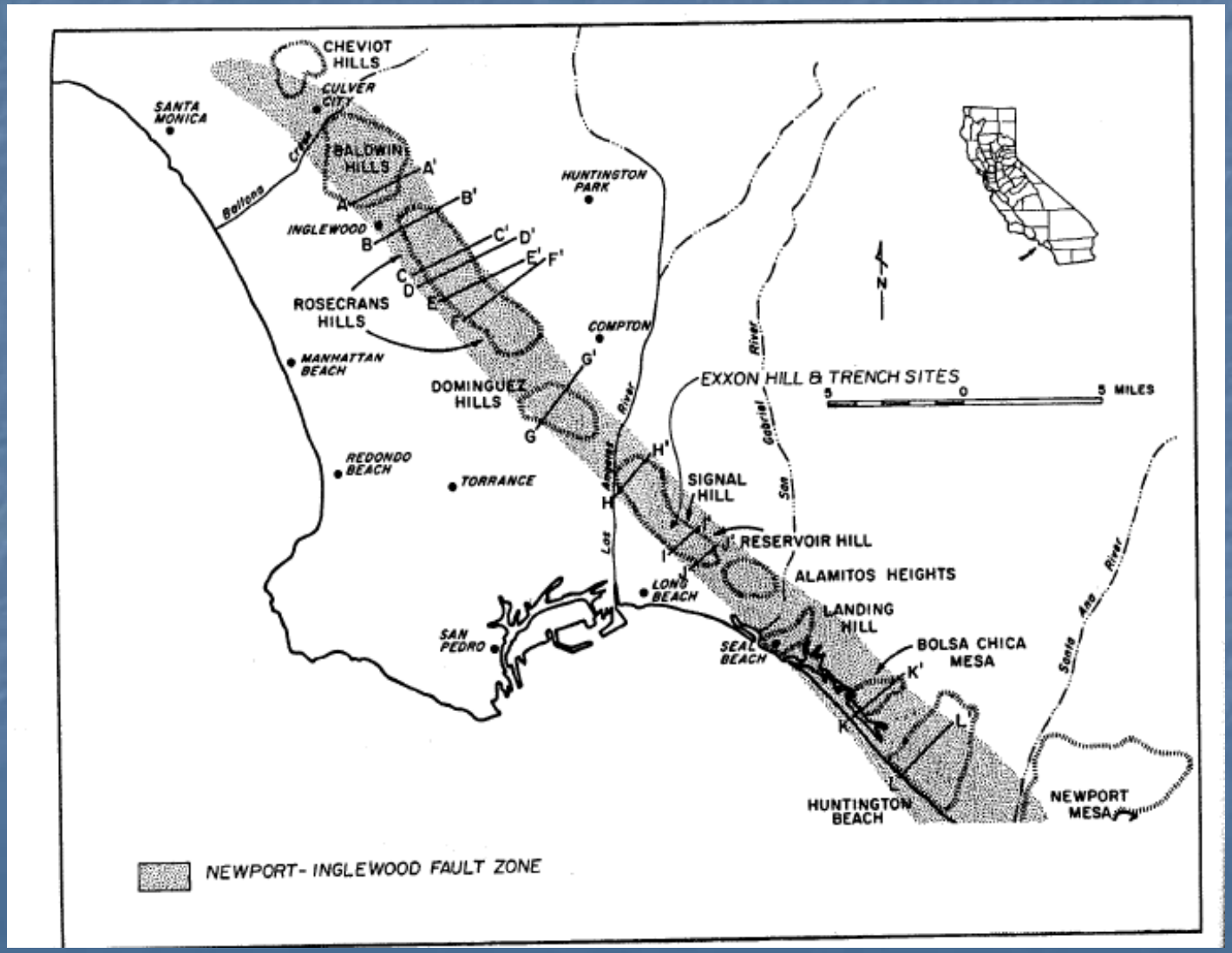
San Joaquin Hills

- Western-most range in Peninsular Ranges
- Bounded by Irvine Basin on northeast; Newport Bay on northwest and the Newport-Inglewood Fault on the southwest.
- Similar rocks to Santa Ana Mountains
- SJH represents a structural anticline with axis trending northwest-southeast
- Sespe Formation is found in northeast portion of SJH – nonmarine formation with vertebrate fossils of oreodonts, camels, rodents…

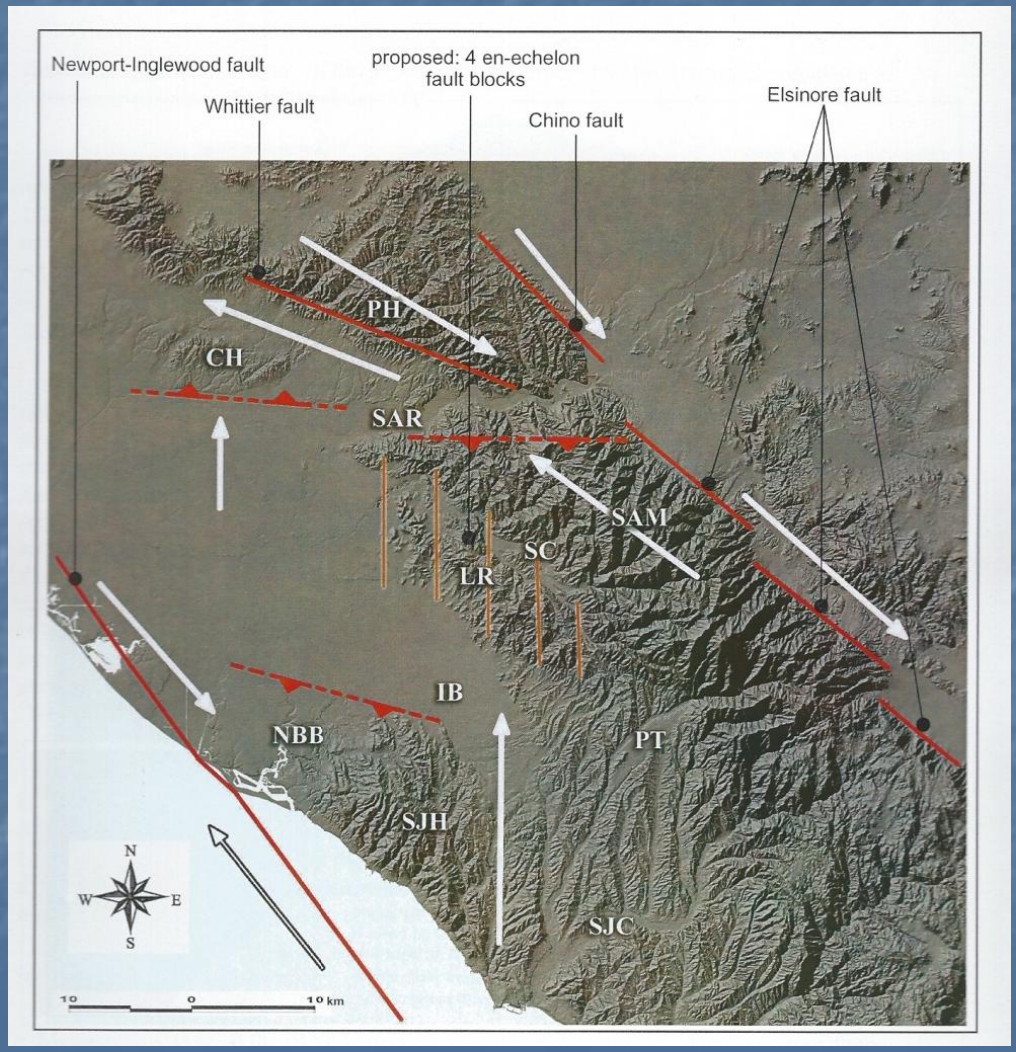
Fritsche & Behl, 2008

Topanga Formation

Newport-Inglewood Fault Zone



Faults in SJH and N. Santa Ana Mts.

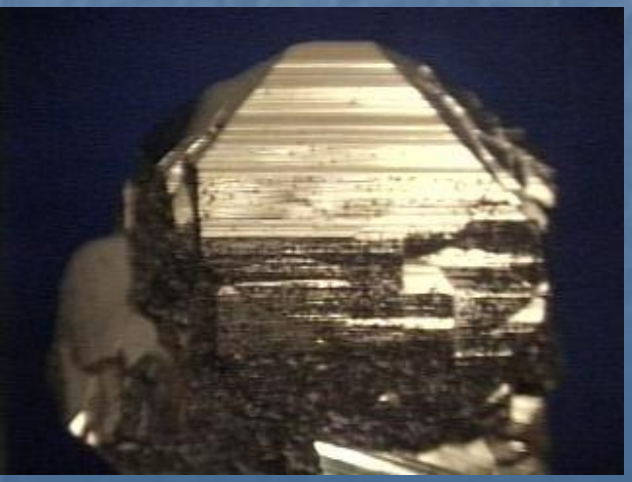


Fritsche & Behl, 2008

Gold: State Mineral

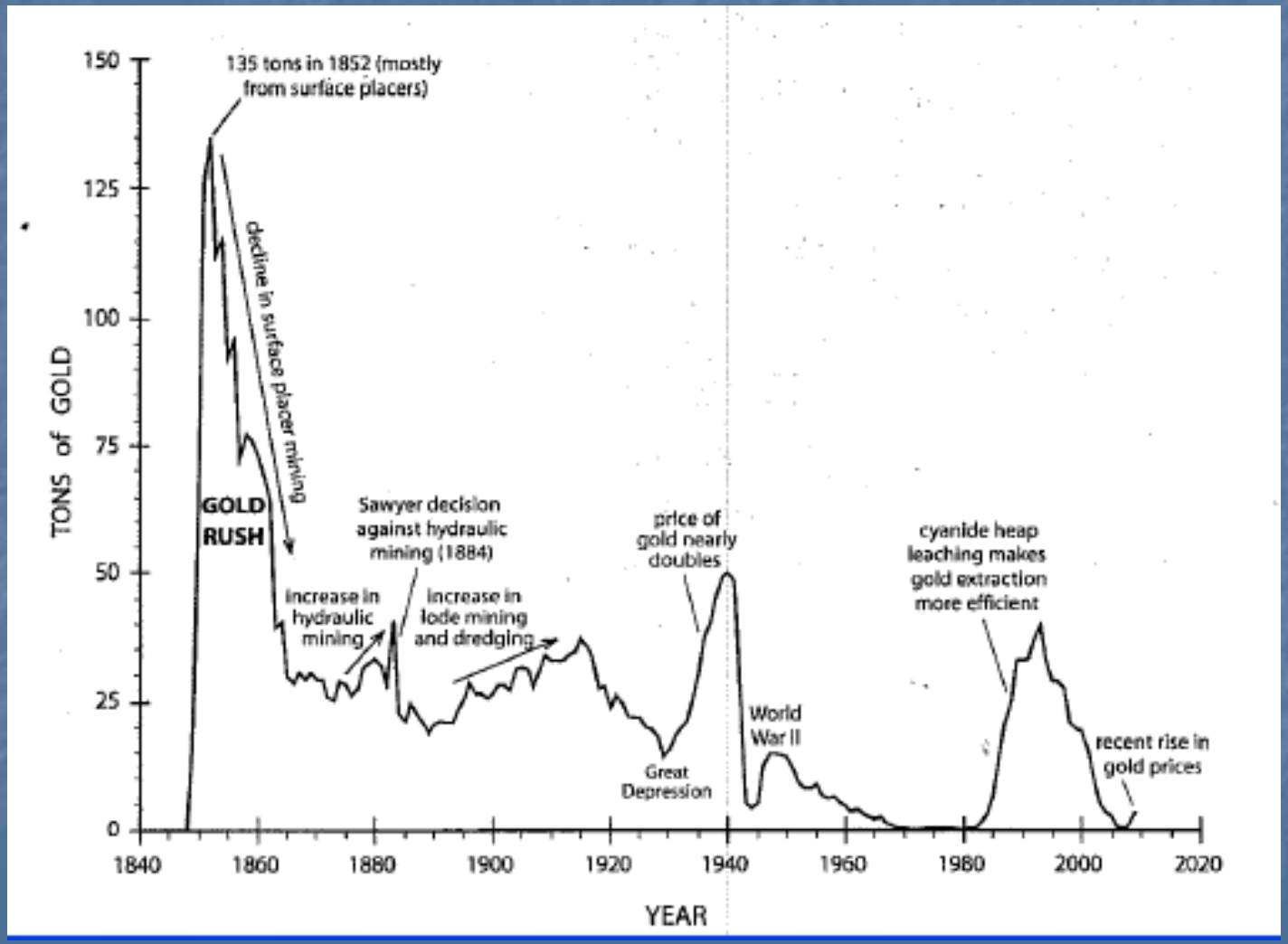
- Au (chemical symbol)

Pyrite (FeS_2) fools gold



http://www.consrv.ca.gov/CGS/information/Pages/EdResCenter.aspx

Gold Production in California



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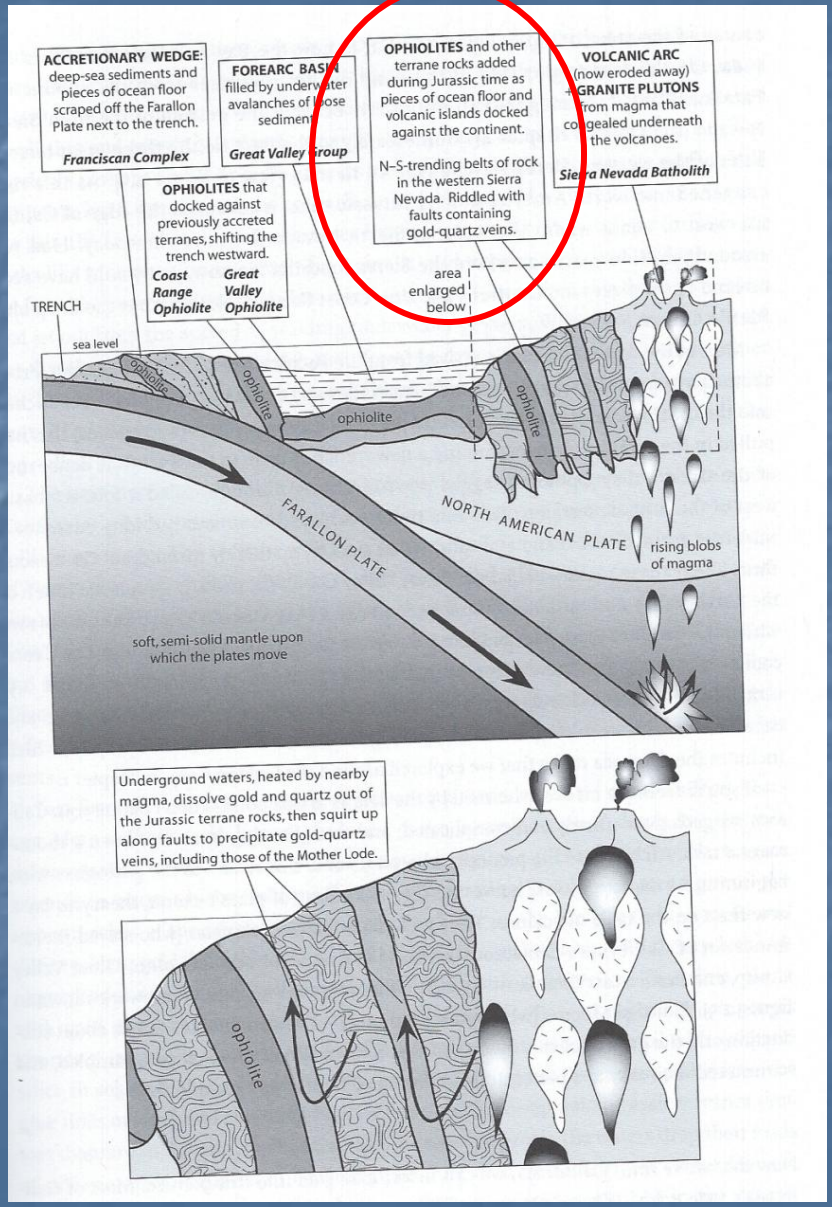
Formation of Sierra Gold Deposits



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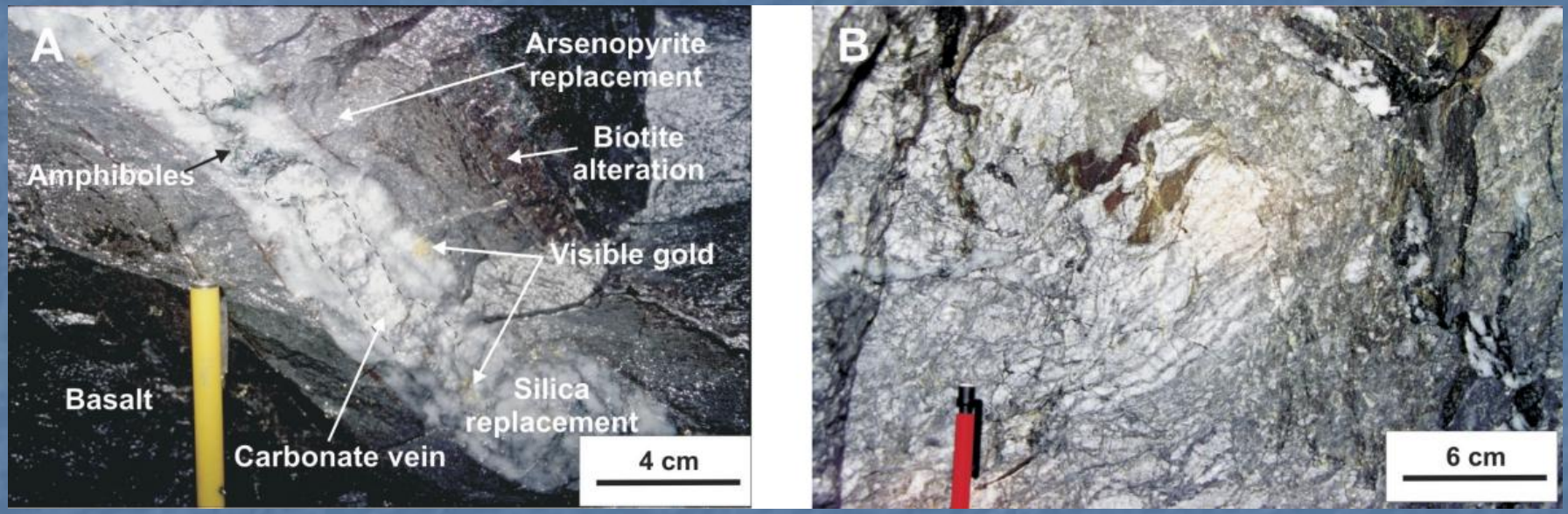
Formation of Lode Deposits

1. Originally, gold element deposited in oceanic rocks
2. Hydrothermal fluids, heated by magmatic plutonic activity, cause the gold to migrate through fractures
3. Metal-rich quartz veins emplaced across plutonic/metamorphic rocks
4. ~100 M.y. emplacement age

Lode Deposits



http://gsc.nrcan.gc.ca/mindep/synth_dep/gold/greenstone/index_e.php

Mining Lode Deposits

- Underground Mining
  - Shafts & tunnels dug
  - Stamp mills crush gold-bearing rock
  - Mercury added to crushed rock
- Open Pit Mines
- Heap Leaching
  - Dissolve gold with cyanide

Placer Deposits

- Gold concentrated in river or beach sediment
- Placers: 40% of California's gold take
- Mining techniques:
  - Panning
  - Sluice box
  - Hydraulic mining
  - Dredging

Gem Deposits in Peninsular Ranges (San Diego County)

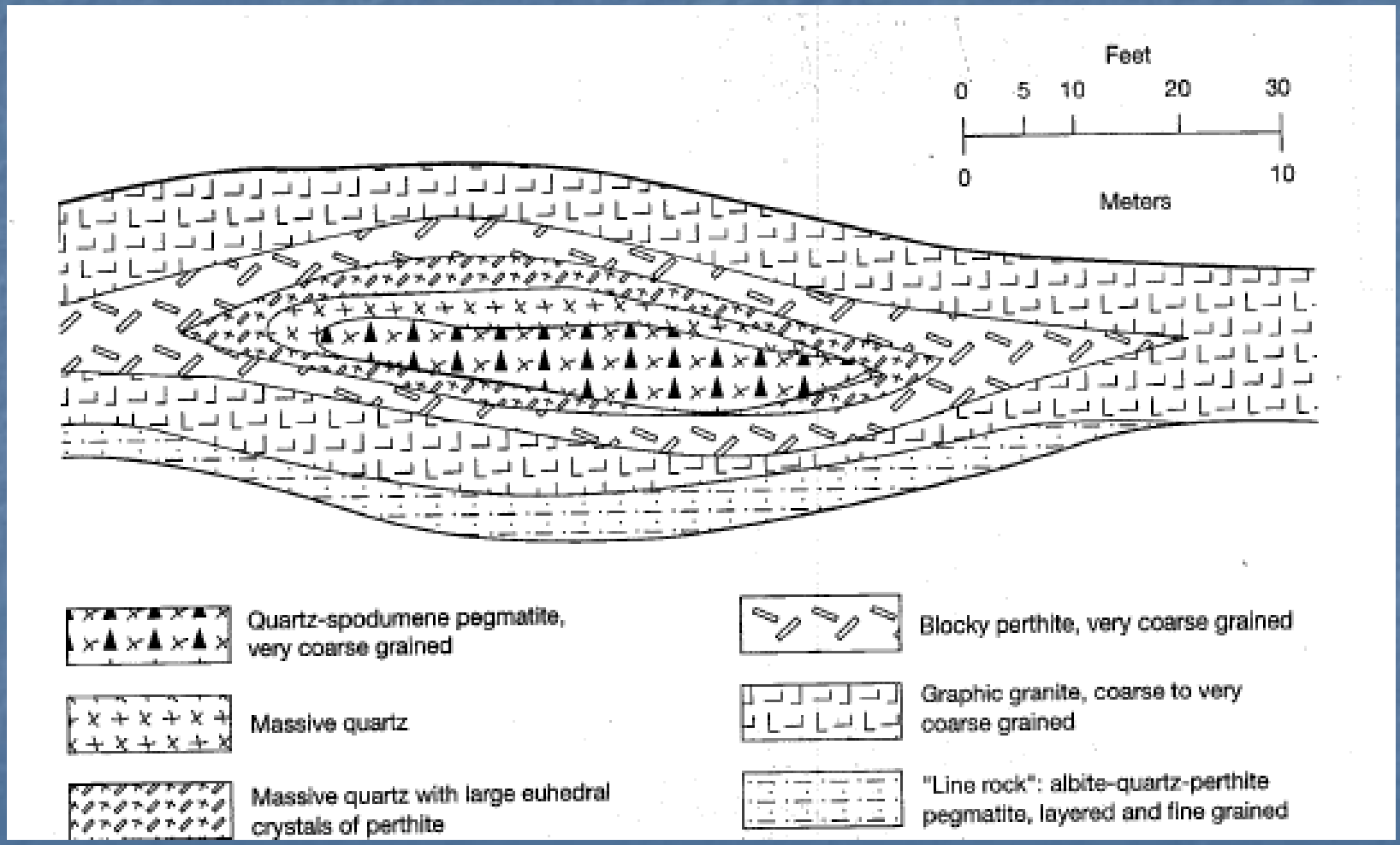
- Gems are associated with pegmatites

- Pegmatites are coarse-grained, quartz-rich plutonic rocks that are intruded into granites and other existing rocks

Gemstones found in San Diego Mines

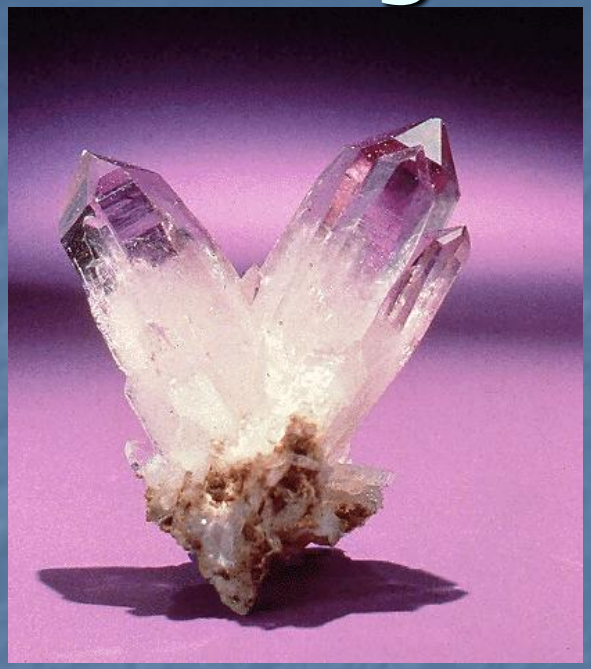
- Quartz SiO_2
- Tourmaline $(Li,Na)HAl_6B_2Si_4O_{21}$
- Beryls $Be_3Al_2(SiO3)_6$
- Morganite (pink beryl)
- Kunzite $LiAl(SiO3)_2$
- Lepidolite $(KLi_2Al(Al,Si)_3O_{10}(F,OH)_2$

Schematic of Gem-bearing Pegmatite



Common Rock-forming Minerals

Quartz



Plagioclase

Feldspars

Orthoclase

Iron-rich Minerals

Pyroxene

Olivine

Hornblende